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THE WATER SUPPLY OF MANILA FROM UNDERGROUND SOURCES

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THREE PLATES AND THREE TEXT FIGURES

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INTRODUCTION

The water supply of Manila comes from two main sources; namely, the water system of the Metropolitan Water District and artesian wells. For washing, bathing, and other domestic needs the people of Manila use the water of the Metropolitan Water District, but for drinking purposes they show a decided preference for artesian-well water. It should be stated, however, that chemical and bacteriological analyses of tap water of the Metropolitan Water District have indicated that it is just as suitable for drinking purposes as water from the artesian wells. There are, of course, residents of Manila who use distilled water from the ice plants.

The artesian wells represent the main source of supply of the general public for their drinking water. There are at present twenty public artesian wells within the boundary limits of the City of Manila and about an equal number of private artesian

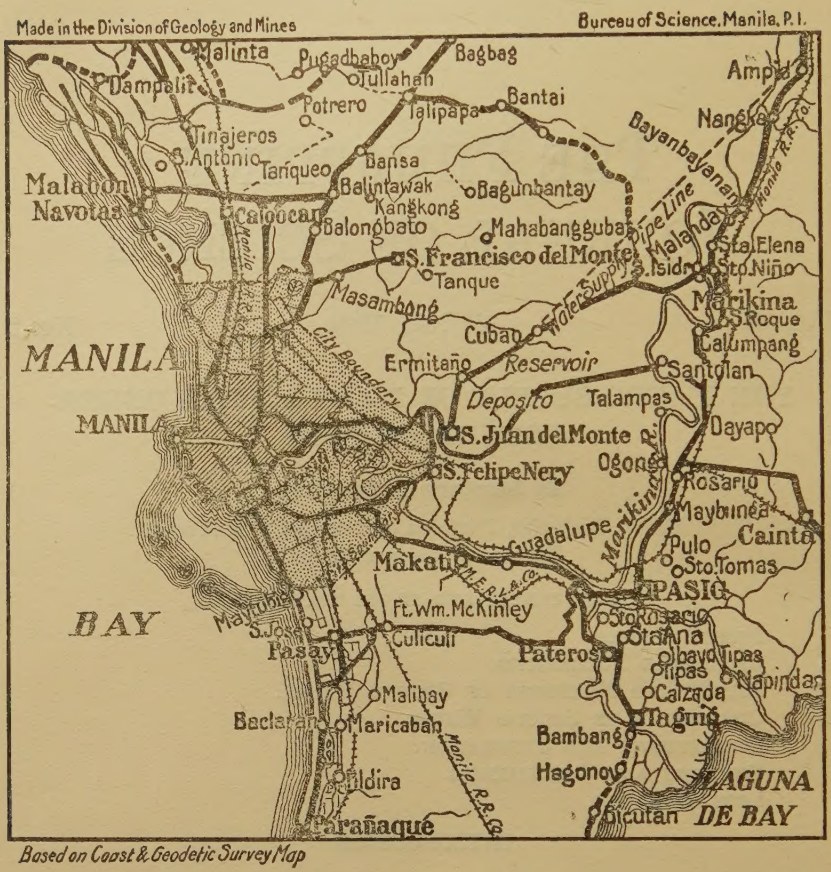

FIG. 1. Manila and neighboring towns.

wells. The public artesian wells located in the more-populous districts are crowded with water carriers from early morning to almost midnight, and many of the private artesian wells are likewise busy all day either filling demijohns of customers or their own demijohns for delivery to residences. It is estimated that these artesian wells, together with those in the vicinity of Manila, numbering more than one hundred, are supplying about 2,700 cubic meters (712,800 gallons) of drinking water per 12-hour day. It is the purpose of this article to describe the geologic occurrence of this artesian water, which is the source of drinking water for the majority of the population of Manila and neighboring districts. For the chemical analyses of the artesian water the reader is referred to the article by Aguilar and Ocampo, following in this issue.

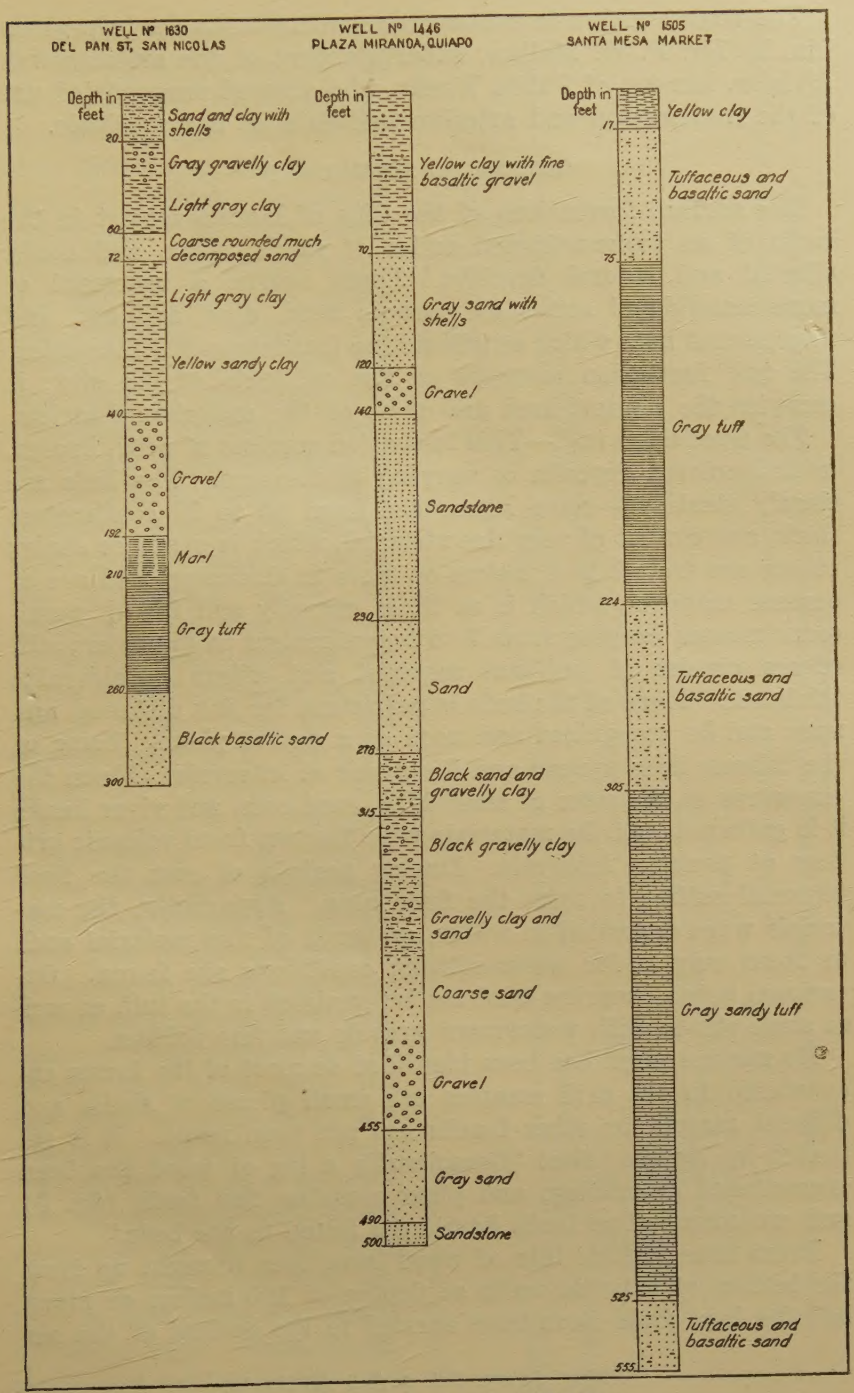

FIG. 2. Sections of wells in Manila.

The writer wishes to acknowledge with thanks the help given him by Mr. F. W. McCaw, superintendent of the artesian-well division, Bureau of Public Works, who allowed unrestricted use of the information and artesian-well data he has available.

GEOLOGICAL FORMATIONS

The surface formations of the City of Manila consist in the main of an unconsolidated series of sands, clays, and muds, alluvial and littoral deposits. These overlie a basement of more-consolidated series of volcanic sand, dust, and ash, and intercalated beds which constitute the Guadalupe-tuff formation. The tuff formation outcrops on the outskirts of the city; it occupies the highest land and most of the suburban districts.

The Guadalupe tuff.—This formation consists of gray, brown, or buff-colored deposits of varying thicknesses. The beds are clearly stratified—some layers are from 10 to 15 centimeters thick, and consist of very fine material, which is sandy or shaly; others are from 3 to 4 meters or more in thickness, and are of coarser material, which is at times gravelly and full of pumiceous masses ranging from 3 to 5 centimeters in diameter; still others consist of uniform material and attain considerable thickness. None of the beds is persistent for any distance, and none can be recognized and used as a datum plane. Some of the thinner beds appear and disappear at intervals. From the exposures on the sides of small hills, road cuts, and river banks it is gathered that the materials were thrown from volcanic orifices at periodic intervals. During periods of rest the finer material settled to form the finer beds. Apparently, the materials were deposited in water, as bands of fine material such as form only under water-settling conditions are found. Occasional beds of marine sand are intercalated in the tuff, as well as some strata with waterworn gravels and fine pebbles.

No marine fossil has been identified as most of the forms encountered in the drill samples are small pieces of shells and diligent search for other fossils has not been made. It is reported by Adams [1] that "Occasionally a log of wood has been encountered in drilling, and plant remains, fish teeth (fig. 3) and one mammalian tooth have been found in the beds."

From time to time bits of wood have been brought up from the bottom of artesian wells at depths of 100 meters or more, but the logs could have been carried to the bottom of the sea

[1] Philip. Journ. Sci. § A 5 (1910) 73.

by running water. However, on the higher portion of the tuff formation, plant remains and perfect leaf impressions have been found, which would seem to indicate terrestrial conditions. The fish teeth reported by Adams are probably not shark's teeth, which are generally pointed and have a cutting edge. The figures that he presented are apparently grinding teeth. Specimens in the collection of the division of mines, Bureau of Science, presumably shark's teeth, are now labelled, "Mammal Artiodactyl tooth. W. Granger." On the basis of structural relations of the tuff to the other formations in the region rather than on the meager fossil data, the Guadalupe-tuff formation has been assigned to the Pliocene.

Quaternary alluvium.— These beds are Quaternary deposits of Recent age and occupy most of the low ground. At depths of 1 meter or more marine shells are encountered. Some of these deposits are so recent that they have not had time to leach their salt content. The salt water from Manila Bay has easy penetration through these beds, which represent the mingling zone of fresh water and salt water; in fact, it is the brackish-water zone. These sands, clays, and muds, alluvial and littoral deposits, have no ap-

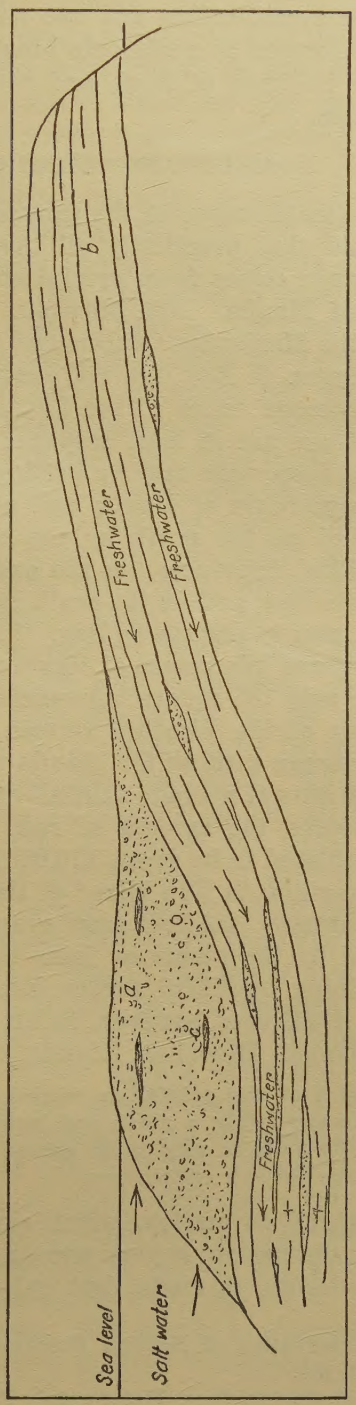

FIG. 3. Geologic section east and west across Manila and vicinity, diagrammatic; showing artesian conditions; *a*, alluvium; *b*, tuff; *c*, impervious material.

parent stratification and are simply loose unconsolidated materials formed by sediments brought down by the rivers, particularly in times of flood, and reworked by the waves and other agencies.

SOURCE AND MOVEMENT OF GROUND WATER

The main source of the ground water is the rainfall. It may be said that practically all the ground water under the City of Manila comes from precipitation upon the regions north and east of Manila. For purposes of this paper it is considered that the Mariquina Graben and the country to the east, as well as Laguna de Bay, are not contributing a great amount to the underground water of the City of Manila, although it is known that there are at least seepages from this area and that some of the deep wells may be getting water from this source. The drainage basin of Manila and neighboring districts is the area bounded on the north by the boundary line between Bulacan and Rizal Provinces, on the east by Mariquina River and Laguna de Bay, and on the south by a line drawn from Parañaque, Rizal, east to Laguna de Bay. This area contains approximately 350 square kilometers of territory, but for the purposes of this paper only 135 square kilometers of surface is considered. The records of the Weather Bureau show that from 1865 to 1923 the average rainfall for Manila was 2,018.7 millimeters. Based on the annual average rainfall and drainage basin of 135 square kilometers, the amount of rain water falling during the year is calculated to be about 270,000,000 cubic meters.

According to Van Hise,[2] of the water which falls on the land substantially one-half soon evaporates, about one-sixth is consumed by the plants or joins the underground water, and the remaining one-third passes into the rivers and goes into the sea. Lindgren, however, in his report on the water resources of Molakai, Hawaiian Islands, says in part:[3]

> A part of this rainfall is carried off by evaporation, another part by the streams, while a third and largest part sinks into the ground and gradually finds its way to the ground water, which permanently saturates the rocks below a certain level.

The tuff formation, which covers most of the drainage area under discussion, is very porous, but in order to be conservative the estimate is made that only one-fifth of the total rainfall

[2] Conservation of Natural Resources in the United States, MacMillan (1927) 107.

[3] U. S. Geolog. Surv. Water-supply Paper 77 (1903) 26.

joins and forms part of the underground water. It would not be surprising when records become available to find that more than one-fifth of the water goes underground, at least for this particular area. The total amount of water per year that goes to form part of the underground supply is estimated at 54,000,000 cubic meters, or approximately 14,000,000,000 gallons. At the present time it has been calculated that the artesian wells of the City of Manila and neighboring districts are supplying water at the rate of 2,700 cubic meters per 12-hour day, or 985,500 cubic meters per year. This calculation is based on the actual capacity of the eighty wells in Manila and neighboring municipalities reported by Aguilar and Ocampo as 2,498 liters per minute, or an average of 31 liters per minute per well, plus twenty-two private wells in Manila and about eighteen wells outside of Manila, all assumed to have the same capacity. Of the 54,000,000 cubic meters available underground, there is being utilized less than a million cubic meters. In other words, the capacity of the reservoir rock below and the source is barely utilized. An increase of ten times the present number of artesian wells would still leave plenty to spare.

Water falling on the ground fills the pore spaces between grains or particles and cavities in the rock formations. As more water falls all the voids and pore spaces and all the cavities begin to be saturated. There is a certain level beneath the surface below which there is complete saturation. This level, which follows more or less the topography of the surface, is known as the ground-water table, or simply the water table. The ground water moves under the influence of gravity from higher levels to lower levels. Ground water on the higher portions of Manila and environs moves downward and outward until it reaches the lower portions of Manila and either discharges into the small streams or into Manila Bay or remains underground. It is natural to suppose that there is a lot of movement on the higher levels or in the higher regions north and east of Manila and that under Manila the ground water has little or no movement and is naturally sluggish. As the ground water in the higher outlying districts has been moving constantly it has not been able to dissolve as much other material as the standing ground water in the lowland areas. The sluggish, practically still water under the City of Manila has more time and opportunity to dissolve materials than the water moving downward from the higher levels. The results of chemical analyses of the water were conclusive in their testimony. All the

wells in the higher outlying districts have less total solids than those in the lowland areas of the City of Manila.

OCCURRENCE OF GROUND WATER

In a humid country like the Philippines the ground-water table is near the surface and during the rainy season in Manila it is at the surface. There are several fresh-water-bearing strata under the City of Manila, but apparently the most important ones all belong to the tuff series. The first stratum from which fresh water is obtained is the one lying beneath the soil and consists of fine sand and gravel mixed with clay. The water available from this source is unsanitary and is insignificant in quantity, due to the fact that it represents merely seepages from neighboring areas and at times is only a thin sheet buoyed up by salt water from Manila Bay.

The ground water of importance is contained in the tuff series and in the tuffaceus sand and other sands. The first water-bearing stratum of these series that has yielded considerable water is met with at about 100 meters below the surface of Manila, which is about a meter above sea level, and from this depth down to about 350 meters water has been obtained at more or less regular intervals. The deepest well in Manila at the present time is the Manila Railroad Company well at Tutuban Station.

The tuff series outcrops to the north and east of Manila and dips gently to the west to Manila Bay. The series consists of beds of very fine material, sometimes impervious, and beds of coarser, and often porous material. The porous beds admit water and are the water-bearing strata. In the upland areas northeast of Manila there are two water-bearing beds; one at a depth of between 60 and 80 meters and one between 120 and 150 meters. The intervening zone is a dry bed. The porous beds extend downward and westward to Manila Bay and represent the water containers. They may have split at their lower portions and some parts may have become impervious, or certain portions may have formed structures that will not permit water to pass through. The subsurface conditions under the City of Manila are such that fresh water may be expected below an impervious stratum, which would shut off the salt water, at depths of 100 meters or more. The salt water above 100 meters, sometimes reaching to greater depths, has saturated the voids and pores of the sand, gravel, littoral, and other material, and

is the main source of contamination, either through excessive pumping or defective casings.

DEVELOPMENT AND UTILIZATION

The ground water under the City of Manila is made available by means of wells, either dug, driven, or drilled. Dug wells are generally shallow, usually not over 20 feet deep, sometimes rimmed at the opening with tuff blocks; the water is lifted by means of rope and bucket. There are very few of these wells now in use, as most of them have either been condemned by the Bureau of Health or voluntarily abandoned by their owners. The remains of some of the wells can still be seen at the back or side of some of the old houses and represent mere relics of the past. Driven wells are a little deeper than dug wells, and are constructed by driving into the ground a small pipe with a drive point. They are driven with a sledge hammer or special driving machinery, sometimes homemade. They are generally less than 30 meters in depth and represent an intermediate type between dug wells and artesian wells.

Artesian wells in the City of Manila are generally 100 meters or more in depth. The casings used are 10, 8, 6, and 4½ inches in diameter. They are usually drilled by the churn method. Most of the wells are pumping. As a matter of fact, from 1904 to 1929, inclusive, only three flowing wells have been encountered and all these have ceased to flow and are now pumped. The capacity of these wells varies from 6 to as much as 85 gallons per minute.

Some of the wells have been abandoned on account of contamination by salt water. There are differences of opinion regarding the source of this contamination. Opponents of artesian-well drilling point to what they term inadequate supply. It has been shown elsewhere in this article that not only is there an adequate supply but that more than the same number of wells now existing can be drilled. It is admitted that drillers have encountered salt water at different intervals and that sometimes fresh water and salt water have been brought up alternately in the course of drilling operations, but in the opinion of F. W. McCaw, superintendent of artesian wells, Bureau of Public Works, the salt water comes from the overlying salt-water-bearing strata and is drawn through the bottom of the loose casing by pumping from above. All the wells drilled in Manila have brought up fresh water at the beginning and only

TABLE 1.—*Successful artesian wells drilled in the City of Manila from 1904 to January 28, 1930.*

[Data furnished by the artesian-well section, Bureau of Public Works.]

Well No.	Location; street or barrio.	Depth.	Diameter of casing.	Capacity in gallon per minute.	Date completed.	Cost.
		Feet.	*Inches.*			*Pesos.*
D-1	Engineer Island	582	----------	P. 28	Dec. 31, 1904	4,855.13
D-2	Singalong Farm	606	----------	P. 78	Jan. 31, 1905	3,381.14
D-431	Bureau of Science	585	10	P. 30	Sept. 16, 1912	3,632.00
D-454	Philippine General Hospital	450	10	P. 85	Oct. 10, 1912	1,174.99
D-518	Government Ice Plant	751	6; 8	P. 25	Sept.11, 1913	6,239.31
D-1396	Santa Ana, Plaza Hugo	543	6	P. 6	Sept. 8, 1919	5,076.64
D-1433	Calle Jesus, Pandacan	470	6	P. 10	Nov. 6, 1919	4,473.30
D-1446	Plaza Miranda, Quiapo	500	6	P. 10	Dec. 20, 1919	7,054.54
D-1456	Magdalena Street, Trozo	847	6	P. 44.5	Feb. 15, 1920	7,964.99
D-1479	San Lazaro, Calle Blumentritt	322	6	P. 60	Feb. 27, 1920	4,463.73
D-1505	Santa Mesa Market	555	6	P. 9	Mar. 27, 1920	4,454.93
D-1528	San Lazaro Hospital	880	4.5; 8	P. 50	June 12, 1920	7,256.26
D-1544	Manila Hotel	427	8	P. 60	June 15, 1920	6,315.42
D-1571	Manila Railroad Company	1,160	6	P. 65	Nov. 11, 1920	9,791.65
D-1578	Manila Hotel	515	8	P. 60	Aug. 20, 1920	7,431.69
D-1599	Anak Bayan Street, Paco	505	8	P. 35	Sept.20, 1920	4,876.42
D-1612*	Juan Luna, Gagalangin	390	8	P. 50	Nov. 17, 1920	4,901.46
D-1616	Ayala & Company	560	6	P. 25	Nov. 24, 1920	4,196.83
D-1629	Santa Clara School	445	6; 4.5	P. 15	Dec. 29, 1920	3,692.68
D-1630	Del Pan Street, San Nicolas	300	6	P. 50	Dec. 19, 1920	2,601.02
D-1634*	Private, La Salle College	670	4.5	P. 38	Mar. 4, 1921	6,293.23
D-1658	Malate Market	650	6	P. 40	Mar. 21, 1921	5,627.15
D-1665	Manrique Street, Sampaloc	445	6	P. 12	Feb. 17, 1921	3,633.70
D-1674	Antonio Rivera Street, Tayuman	359	4.5	P. 30	Mar. 22, 1921	4,696.65
D-1675	Paco Market	330	6	P. 50	Mar. 22, 1921	2,763.26

D-1688 [a]	Maria Clara Street, Sampaloc	295	6; 8	P. 60	Apr. 26, 1921	3,224.69
D-1689	O'Donnell Street	385	6	P. 60	Apr. 30, 1921	3,328.09
D-1894 [a]	Herbosa Street, Tondo	460	6	P. 50	Feb. 26, 1923	4,220.71
D-1921	G. Tuazon and Santiago Streets	525	6; 4.5	P. 45	June 28, 1923	4,512.59
D-1929	Esguerra Street, Tondo	390	6	P. 30	Aug. 2, 1923	3,306.26
D-1939	Muralla Street	730	4.5	P. 10	Nov. 9, 1923	6,038.10
J-16079	Royal Ice Plant, San Miguel	795	6	P. 30	Oct. 7, 1924	5,649.05
D-2111	Bureau of Prisons	650	6; 4.5	P. 30	June 9, 1925	5,412.92
D-2293	Philippine General Hospital	837	8; 6; 4.5	P. 15	Oct. 12, 1926	6,837.85
J-16768	Army and Navy Y. M. C. A., Intramuros	872	8; 10	P. 30	Jan. 6, 1927	9,606.01
D-2425	Plaza de la Virgen, Pandacan	670	6	P. 25	Feb. 20, 1928	7,122.94
D-2472	Bilibid Prison	800	6	P. 35	Nov. 7, 1928	
D-2613	Plaza Braulio, Tondo	493	6	P. 50	Jan. 28, 1930	

[a] No longer in use; closed or salty.

after some time have a few turned salty. It should also be remembered that salt water attacks iron pipes with ease and after a number of years leakage may occur. McCaw, however, claims that during the last five years he has found only one instance in which the casings have been corroded and have shown holes. This was the case of well No. 856, located on Dominga Street, Pasay, Rizal. The well was drilled during the latter part of 1915. It is 580 feet deep, has 460 feet of 6-inch casing and 567 feet of 4½-inch casing. About two years ago the well turned salty. The Bureau of Public Works pulled the 4½-inch casing during the latter part of 1930 and found the lower 300 feet coated with a crust one-third of an inch thick and badly corroded. Apparently, the casing is loose, as is shown by the formation of the crust outside of the pipe.

Salt water can be shut off entirely by cementation; that is, by cementing at the bottom of the well in such a manner that all the water passages are shut off.

The rôle that these artesian wells play in the routine life of the City of Manila is not fully realized, except when other supplies of potable water are cut off or dwindle to an alarming minimum. At such a time the artesian wells represent the main source of drinking water. From early morning, as early as 4 o'clock, and until late at night, water carriers can be seen at the different wells filling their 5-gallon cans, either for their own use or for sale in the neighborhood. At Plaza Miranda, Quiapo, at Blumentritt, San Lazaro, and at Magdalena Street, Trozo, the stream of water carriers is almost without break. In addition there are several private companies with wells of their own that are selling water at their plants or delivering it to their customers at their residences. Some employ their wells for private use entirely.

The value of these artesian wells to the City of Manila cannot be overestimated. During the rainy season of 1929 the main pipe of the Metropolitan Water District across Mariquina River broke and Manila was face to face with the possibility of having no water for domestic use. While workmen were frantically working to make the necessary repairs, and officials of the Metropolitan Water District in the City of Manila were calling upon the public to economize in the use of water, the population turned to artesian wells for their entire water supply and all the wells were pumped to their capacity. Lines of water carriers extended sometimes across a city block and not a few personal encounters were registered. Fortunately for the City of

Manila the water crisis lasted only a few days. What happened in 1929 may happen again. It is only necessary to call attention to the fact that Manila is in the earthquake belt and that a more-serious break in the water mains is possible. The artesian wells represent first aid of prime magnitude. In this connection the experience of Japan during the 1923 earthquake is here recalled. When the water mains of Yokohama broke and the city was without a water supply the one source of drinking water was a lone dug well in one of the sacred-temple grounds.[3] The lesson is for a city as large as Manila to have several sources of good drinking water.

The one and most important use of underground water in Manila is for drinking purposes. The industrial uses made by ice plants and other establishments are small and represent but a very small fraction of the total consumption.

TABLE 2.—*Private artesian wells in the City of Manila.*

[Data furnished by Mr. Santiago Artiaga, city engineer of Manila.]

Name.	Location.	Depth in feet.	Pumping gallons capacity; per minute.
Watson & Co	504 Aviles	(a)	(a)
La Humildad	Del Pan Street, San Nicolas	(a)	(a)
Sternberg General Hospital	Concepcion Street	(a)	(a)
La Rosario	1001 R. Hidalgo	(a)	(a)
Adelante No. 1	1338 Juan Luna	(a)	(a)
Adelante No. 2	do	386	(a)
Magnolia	660 Echague	600	25
San Beda	E. Mendiola Street	(a)	(a)
La Yebana	57 Gastambide	479	15
Heacock	Escolta, corner of David	1,000	60
La Tondeña	1068 Velasquez	1,002	45 to 50
San Miguel Brewery	132 Aviles	693	15

[a] No record.

SUMMARY AND CONCLUSIONS

As a result of the present studies of the underground water supply of Manila the following conclusions are reached:

1. The underground water supply is sufficient to support at least ten times the number of artesian wells now existing, and more if necessary.

[3] Personal communication from Dr. Otto Schöbl, Bureau of Science, Manila.

2. The fresh-water-bearing strata as a source of good drinking water are encountered at intervals from 100 meters down to 350 meters below the general level of the city, and probably at greater depths.

3. The records show that the wells that have been abandoned have been closed on account of the presence of salt water. Apparently the cause can be found either in loose casings or portions of the casings that are easily attacked by salt water and that in the course of time develop leaks through which salt water is pumped.

4. It is recommended that in the future all drillers after passing through salt-water-bearing strata pull their casing and properly put in cement at the bottom of the well in such a manner as to prevent salt water from again entering the well.

5. The danger of contaminated artesian wells is not in the water, which these wells bring up from the underground deeps, but in their use and construction and in the care given to them.

6. For the safety of the general public and to insure Manila a steady supply of good drinking water within reach of the poorest inhabitant, the water supply of the Metropolitan Water District should be supplemented with more artesian wells.

7. Future sites of artesian wells should be determined by a consideration of geology, number of wells in the vicinity, density of population, needs of the district, cost, and other factors.

LOGS OF WELLS

The logs of the different wells are here given based on the determinations made on the samples as submitted to the Bureau of Science. They are recorded here so that they can be checked by future drillers. The wells are arranged by districts, in alphabetical order. The depths are in feet as reported by the Bureau of Public Works. The location of these wells is indicated on Plate 1 of the following article, by Aguilar and Ocampo.

ERMITA

WELL No. 431.

Location: Bureau of Science, Herran and Taft Avenue.
Depth, 585 feet.
Cased.
Pumps 30 gallons per minute.

Feet.	
0– 20.	Greenish clay containing shells.
20– 45.	Clay with fine basaltic pebbles, and a large amount of shell fragments.
45– 55.	Calcareous material with limestone fragments.

Feet.
55– 65. Same with more limestone, shell fragments, and grains of basaltic material.
65– 71. Fine brownish sand, some shell fragments, some pebbles.
71– 75. Coarser sand with shell fragments and coarse rock fragments.
75–100. Light brown clay with shell and rock fragments.
100–105. Stiff yellow clay.
105–110. Sandy yellow clay with some red iron-stained fragments.
110–116. Stiff reddish clay.
116–120. Red shale.
120–132. Stiff yellow clay with pebbles.
132–147. Black clay with pellets of manganese oxide.
147–155. Stiff brownish clay with fragments of limestone.
155–165. Fine black gravel and yellow clay.
165–180. Yellow sandy clay with some gravel.
180–225. Sand and gravel.
225–256. Fine yellow sand with some clay material.
256–314. Coarse gray sand.
314–336. Fine yellow sand with some pebbles.
336–348. Coarse sand.
348–350. Wood fragments.
350–367. Black argillaceous mud.
367–385. Coarse sand, black.
385–405. Coarse sand, dark, with quartz, feldspar and olivine grains.
405–435. Yellow sand.
435–450. Gray sandy clay.
450–472. Very light gray clay.
472–500. Coarse yellow sand.
500–525. Coarse sand, angular fragments, brownish black, rather clean.
525–550. Light brown argillaceous gravel.
550–565. Coarse brown sand like "336–348."
565–585. Bluish stiff clay, roof of water.

WELL No. 1544.

Location: Manila Hotel, Port Area.
Depth, 427 feet.
Cased 368 feet.
Pumps 60 gallons per minute. Water stands 5 feet below the surface.
Determinations by L. A. Faustino.

Feet.
0– 60. Gray clay with shells.
60–136. Black clay with shells.
136–187. Gray tuff with shells.
187–250. Sandstone.
220–250. Sand.
250–310. Gray sandy tuff.
310–320. Tuffaceous sand with coarse gravel.
320–360. Yelow tuff.
360–380. Gray sandstone.
380–420. Tuffaceous sand.

WELL No. 1578.

Location: Manila Hotel, Port Area.
Depth, 515 feet.
Cased 374 feet.
Pumps 60 gallons per minute. Water stands 9 feet below the surface.
Determinations by L. A. Faustino.

Feet.	
0–125.	Gray clay with shells.
125–190.	Gray sticky clay.
190–210.	Pebbly clay with coarse gravel.
210–230.	Coarse gravel.
230–250.	Mixed igneous sand and gravel with shells.
250–267.	Gray sandstone.
267–277.	Tuff.
277–297v.	Gray tuff with fine gravel.
297–320.	Gray sandstone.
320–375.	Yellow tuff.

WELL No. 2293.

Location: Philippine General Hospital, Manila.
Depth, 837 feet.
Cased 833 feet.
Pumps 15 gallons per minute. Water stands 90 feet below the surface and 30 feet below when not pumping.
Determinations by L. F. Abad.

Feet.	
0– 5.	Yellow arenaceous clay.
6– 45.	Gray tuffaceous clay with bits of shells.
46– 60.	Yellow clay with bits of shells.
61– 80.	Calcareous clay.
81–141.	Black fossiliferous clay.
142–150.	Fine and coarse sand.
155–167.	Sand and gravel.
168–235.	Tuffaceous sandstone.
236–250.	Tuffaceous conglomerate.
251–272.	Tuffaceous sandstone.
273–280.	Medium coarse tuffaceous sand.
281–300.	Coarse basaltic sand.
301–320.	Tuffaceous sandstone.
331–340.	Medium tuffaceous sand.
341–360.	Tuffaceous clay.
361–419.	Tuffaceous sandstone.
420–439.	Coarse tuffaceous sand.
440–475.	Tuff.
476–495.	Tuffaceous clay.
496–505.	Very fine quartzose sand.
506–522.	Arenaceous clay.
523–586.	Black clay with coarse basaltic sand.
586–675.	Fine black sand.
676–726.	Medium black sand.

Feet.

747–796. Dark brown arenaceous clay.
796–808. Black arenaceous clay.
809–813. Coarse basaltic sand.
814–830. Black arenaceous clay.
830–837. Black sand.

INTRAMUROS

WELL No. 1939.

Location: Muralla, near Victoria Street.
Determinations by A. D. Alvir.

Feet.

0– 40. Sandy and conglomeratic black clay with fragments of shells.
40–105. Yellow somewhat sandy clay with fragments of shells.
105–130. Bluish gray sandy clay with small shells.
130–160. Small dark moderately well-rounded gravel in a clayey matrix.
160–260. Yellowish gray sandy clay with tiny pebbles of dark material.
260–280. Bluish gray sandy clay with small shells.
280–310. Yellowish gray sandy clay.
310–350. Moderately well-rounded dark pebbles in a clayey matrix.
350–401. Light gray, very argillaceous, coarse sand with a few well-rounded pebbles.
401–408. Brownish to bluish gray, somewhat sandy, sticky clay with well-rounded pebbles.
408–470. Dark gray sandstone with a shiny black constituent, probably hornblende.
470–479. Yellowish gray clay with sand and fine gravel.
479–490. Light gray, probably tuffaceous, very argillaceous sand.
490–500. Gray sandstone.
500–515. Yellowish gray clay with small pebbles and shell fragments.
515–530. Dark gray moderately hard sandstone.
530–585. Medium dark gray sand.
585–595. Gray, probably tuffaceous, very argillaceous coarse sand.
595–597. Dark gray moderately hard sandstone.
597–625. Bluish gray sandy clay with shells.
625–630. Dark gray moderately hard sandstone.
630–633. Semisilicified wood.
633–665. Bluish gray sandy clay with shells.
665–687. Dark gray sand with tiny pebbles.
687–692. Tuff and fine light gray sand.
692–695. Dark gray moderately hard sandstone with some pieces of yellowish gray clay.
695–696. Fine sandy bluish gray clay with shells.
696–705. Dark gray moderately hard sandstone with some pieces of dark clay.
705–716. Fine dark gray sand.
716–730. Gravel, of basalt, well rounded in a matrix of dark sandstone.

WELL-JOB No. 16768.

Location: Aduana Street.
Depth, 872 feet.
Cased 172 feet.
Pumps 30 gallons per minute. Water stands 100 feet below the surface.
Determinations by L. F. Abad.

Feet.	
0– 80.	Black arenaceous clay.
80–120.	Tuffaceous clay with shells.
120–130.	Brown arenaceous clay.
130–137.	Coarse basaltic sand with shells.
137–161.	Basaltic gravel.
161–169.	Gray tuffaceous clay.
169–182.	Yellow tuffaceous clay.
182–215.	Black clay with shells.
215–245.	Black sandy clay.
245–255.	Very fine sand.
255–292.	Tuffaceous sand.
292–302.	Fine sand.
302–346.	Tuffaceous clay and sand.
346–371.	Red clay with shells.
371–381.	Basaltic sand.
381–391.	Tuffaceous sand.
391–396.	Basaltic sand and gravel.
396–410.	Basaltic sand with pieces of wood.
410–422.	Arenaceous clay.
422–432.	Clay and coarse sand.
432–438.	Medium sand.
438–446.	Fine sandstone.
446–456.	Yellow sandy clay.
456–471.	Tuff.
471–495.	Brown sandy clay.
495–509.	Tuffaceous sand.
509–527.	Sandy clay.
527–554.	Basaltic sand.
554–557.	Fine basaltic sand.
557–567.	Tuffaceous clay.
567–571.	Fine tuffaceous sand.
571–600.	Very fine black sand.
600–628.	Brown clay.
628–645.	Black sandy clay.
645–655.	Black sand.
655–672.	Gray clay.
672–680.	Tuffaceous and black sand.
680–687.	Yellow sandy clay.
687–692.	Fine tuffaceous sand.
692–700.	Coarse tuffaceous sand.

Feet.
700–736. Medium black sand.
736–740. Sandy clay.
740–750. Very fine yellow sand.
750–760. Yellow sandy clay.
760–766. Gray sandstone.
766–782. Tuff.
782–806. Gray sandy clay.
806–823. Medium black sand.
823–869. Sandy clay.
869–872. Fine black sand.

MALATE

WELL No. 1658.
Location: Market site, Malate, Manila.
Depth, 650 feet.
Cased 569 feet.
Pumps 40 gallons per minute. Water stands 20 feet below the surface.

Feet.
0– 35. Gray tuffaceous clay with shells.
35– 72. Tuffaceous clay, sand, and gravel mostly basaltic.
72–110. Sandy clay with gravel and shells.
110–190. Marly clay with igneous and calcareous gravel.
190–230. Gray tuff.
230–280. Tuffaceous sand and gravel.
280–360. Fine gray tuff.
360–410. Tuffaceous sand.
410–445. Tuffaceous clay and gravel.
445–480. Tuffaceous sand.
480–515. Tuffaceous clay and gravel.
515–530. Fine gray tuff.
530–549. Tuffaceous clay and gravel.
549–571. Gray tuff.
571–610. Yellowish gravelly clay.
610–620. Fine tuffaceous sand.
620–650. Basalt gravel and sand.

WELL No. 2.
Location: Singalong Farm.

Feet.
0–408. No samples.
409–520. Fine gray volcanic ash.
520–535. Gray tuff.
535–570. Fine sand, dark pebbles, considerable quartz.
570–575. Medium sand, dark pebbles, considerable quartz.
575–595. Yellow tuff, rather clayey.
595–600. Gray tuff.
600–605. Fine pebbles, basaltic rock, some tuff.
605–607. Tuff and fine basaltic pebbles.

WELL No. 1634.

Location: La Salle College.
Depth, 970 feet.
Cased 586 feet.
Pumps 38 gallons per minute. Water stands 25 feet below the surface.

Feet.	
1– 43.	Yellow clay with shells.
43– 57.	Gray clay with shells and calcareous gravel.
57– 77.	Dark gray clay with shells.
77–120.	Yellow sandy clay.
120–150.	Tuffaceous sandy clay, light gray.
150–195.	Dark gray clay with shells.
195–220.	Tuffaceous sandy clay.
220–270.	Tuffaceous clay.
270–275.	Fine tuffaceous sand.
275–340.	Tuff.
340–430.	Gray tuff.
430–465.	Fine tuffaceous sand.
465–498.	Coarse tuffaceous sand.
498–534.	Tuffaceous clayey sand.
534–560.	Coarse tuffaceous sand.
560–590.	Fragments of light vescicular lava.
590–635.	Dark fine sand.
635–670.	Very fine sand.

PACO

WELL No. 2425.

Location: Plaza de la Virgen.
Depth, 670 feet.
Cased 593 feet.
Pumps 25 gallons per minute. Water stands 64 feet below the surface when pumping, and 7 feet below when not pumping.
Determinations by L. F. Abad.

Feet.	
0– 30.	Tuffaceous clay.
30– 90.	Yellow clay.
90–160.	Medium sand.
160–200.	Arenaceous clay.
200–225.	Medium sand and coarse gravel.
225–350.	Tuffaceous clay.
350–400.	Medium basaltic sand.
400–415.	Sand and gravel.
415–525.	Gray arenaceous clay.
525–570.	Tuff.
750–600.	Tuffaceous sand.
600–670.	Medium gray sand.

WELL No. 1675.

Location: Paco Market.
Depth, 330 feet.
Cased 324 feet.
Pumps 50 gallons per minute. Water stands 20 feet below the surface.

Feet.	
0– 40.	Dark gray clay with shell fragments.
40– 70.	Yellowish clay with shell fragments.
70– 90.	Tuffaceous sand.
90–110.	Light gray clay.
110–160.	Reddish sandy clay.
160–185.	Light gray clay.
185–200.	Basaltic sand and gravel.
200–230.	Light gray clay, tuffaceous.
230–255.	Tuffaceous sand.
255–278.	Gray tuff.
278–300.	Tuffaceous sand.
300–325.	Light gray tuff.
325–328.	Tuffaceous sand.
328–330.	Basaltic sand and gravel.

WELL No. 1599.

Location: Anak Bayan.
Depth, 505 feet.
Cased 414 feet.
Pumps 25 gallons per minute. Water stands 25 feet below surface.
Determinations by L. A. Faustino.

Feet.	
0– 30.	Gray clay with shells.
30– 80.	Yellow clay.
80–100.	Gray sandstone.
100–150.	Yellow clay.
150–220.	Gray tuff.
220–260.	Tuff.
260–300.	Yellow tuff.
300–330.	Tuff.
330–410.	Gray tuff.
410–430.	Tuff.
430–505.	Tuffaceous sand.

PANDACAN

WELL No. 1433.

Location: Jesus and Narciso Streets.
Depth, 470 feet.
Cased 461 feet.
Pumps 10 gallons per minute. Water stands at the surface.
Determinations by L. A. Faustino.

Feet.	
0– 12.	Black hard clay with shells.
12– 45.	Tuffaceous and basaltic sand.
45–160.	Tuff.
160–456.	Tuffaceous and basaltic sand.
456–563.	Black hard clay with shells.
463–470.	Tuffaceous and basaltic sand.

QUIAPO

WELL No. 1446.

Location: Plaza Miranda.
Depth, 500 feet.
Cased 440 feet.
Pumps 10 gallons per minute. Water stands 7 feet below the surface.
Determinations by L. A. Faustino.

Feet.	
0– 70.	Greenish yellow clay with fine basaltic gravel.
70–120.	Tuffaceous gray sand with shells.
120–140.	Fragments of andesite, sandstone, and quartz.
140–230.	Gray sandstone.
230–278.	Black gravelly clay.
278–315.	Gray sandstone.
315–340.	Gray sandstone and black gravelly clay.
340–370.	Black gravelly clay.
370–400.	Black gravelly clay and tuffaceous sand.
400–440.	Coarse tuffaceous sand.
440–455.	Fragments of andesite, quartzite, and other rock.
455–490.	Tuffaceous gray sand.
490–500.	Gray sandstone.

WELL No. 2511.

Location: Philippine Cold Stores, near Quinta Market.
Determinations by L. F. Abad.

Feet.	
0– 30.	Yellow clay and sand.
30– 40.	Fine basaltic sand.
40– 80.	Gray tuffaceous clay with shells.
80– 90.	Light brown arenaceous clay.
90–110.	Coarse gravel.
110–140.	Clay, sand, and gravel.
140–245.	Tuff.
245–300.	Fine basaltic sand.
300–307.	Tuffaceous sand.
307–317.	Coarse tuffaceous sand.
317–370.	Tuffaceous sand.
370–382.	Arenaceous clay.
382–465.	Mixed basaltic sand and cuttings from tuff.
465–470.	Mixed sand and cuttings from buried wood.
470–500.	Tuffaceous sand.
500–560.	Fine tuffaceous sand and gravel.

SAMPALOC

WELL No. 1688.

Location: Maria Clara Street.
Depth, 295 feet.
Cased 283 feet.
Pumps 60 gallons per minute. Water stands 1 foot below the surface.

Feet.
0– 32. Blue clay with shells.
32– 43. Brown gravelly clay with few shells.
43– 57. Basalt gravel.
57– 90. Gray tuff.
90–120. Dark gray tuffaceous clay.
120–190. Gray tuff.
190–270. Dark gray tuffaceous clay.
270–282. Gray plastic clay.
282–295. Basalt sand and gravel, scoriaceous.

WELL No. 1665.
Location: Manrique and Bustillos, Streets.
Depth, 445 feet.
Cased 225 feet.
Pumps 8 gallons per minute. Water stands at 8 feet below the surface.

Feet.
0– 37. Dark gray tuffaceous clay with shells.
37– 57. Brownish clay with shells.
57–215. Gray tuff.
215–220. Tuffaceous sand.
220–370. Gray tuff like "57–215."
370–425. Tuffaceous sand like "215–220."
425–445. Gray tuff like "57–215."

WELL No. 1505.
Location: Santa Mesa Market.
Depth, 555 feet.
Cased 495 feet.
Pumps 9 gallons per minute. Water stands 3 feet below the surface.
Determinations by L. A. Faustino.

Feet.
0– 17. Yellow clay.
18– 75. Tuffaceous and basaltic sand.
76–224. Gray tuff.
225–305. Tuffaceous and basaltic sand.
306–525. Gray sandy tuff.
526–555. Tuffaceous and basaltic sand (fine).

SAN MIGUEL

WELL No. 1616.
Location: Ayala and Co.
Depth, 560 feet.
Cased 460 feet.
Pumps 25 gallons per minute. Water stands at 40 feet below the surface.

Feet.
1–120. Dark gray clay with shells.
120–130. Tuffaceous sand.
130–250. Gray tuffaceous sand and clay.
255–285. Tuffaceous clay.
285–308. Gray tuffaceous sand and clay.

Feet.
308–325. Gray tuff.
325–420. Tuffaceous sand and clay.
420–470. Gray tuff.
470–495. Tuffaceous sand and clay.
495–525. Gray tuff.
525–560. Tuffaceous sand.

WELL-JOB No. 16079.

Location: San Miguel Brewery, General Solano Street.
Depth, 795 feet.
Cased 540 feet.
Pumps 30 gallons per minute. Water stands 200 feet below the surface.
Determinations by A. D. Alvir.

Feet.
0– 50. Gray tuffaceous clay.
50–120. Same with shells.
120–127. Sandy tuff with shells.
127–140. Gray sandy tuff.
140–155. Gray clayey tuff with many shells and wood fragments.
155–177. Gray sandy tuff.
177–190. Same but much coarser.
190–205. Sandy tuffaceous clay.
205–250. Clay with basaltic pebbles.
250–285. Hard dark clay.
285–356. Tuff.
356–380. Greenish gray clay with fine pebbles.
380–395. Sandy tuff.
395–435. Coarse tuffaceous sand.
435–460. Sandy tuff.
460–508. Greenish gray clay with fine pebbles.
508–525. Sandy tuff.
525–539. Hard tuffaceous dark clay.
539–552. Fine sand with hard shale.
552–579. Coarse tuffaceous sand.
579–613. Greenish gray sandy clay.
613–630. Gray sandy tuff.
630–689. Bluish gray clay.
689–695. Same but harder.
695–735. Fine dark sand.
735–774. Bluish gray clay with fine pebbles.
774–781. Dark sand with clay pellets.
781–795. Gray clay with sand and fine pebbles.

SAN NICOLAS

WELL No. 1630.

Location: Del Pan Street.
Depth, 300 feet.
Cased 230 feet.
Pumps 50 gallons per minute. Water stands at 20 feet below the surface.

Feet.
0– 20. Tuffaceous sand and clay with shells.
20– 40. Gray gravelly clay.
40– 60. Light gray clay.
60– 72. Coarse, rounded, and much-decomposed sand.
72–100. Light gray clay.
100–140. Yellow sandy clay.
140–170. Basalt and andesite gravel.
170–192. Fragments from basalt with rounded gravel.
192–210. Marl.
210–260. Gray tuff.
260–300. Black basaltic sand.

SANTA ANA

WELL No. 1396.

Location: Near Public Market.
Depth, 543 feet.
Cased 539 feet.
Pumps 6 gallons per minute. Water stands 2 feet below surface.
Determinations by L. A. Faustino.

Feet.
0– 46. Broken shells.
75. Gray tuffaceous clay.
132. Basaltic and tuffaceous sand.
137. Yellow tuffaceous sand.
341. Basaltic scoria.
353. Tuffaceous yellow clay with fine gravel.
415. Gray tuff with shells.

SANTA CRUZ

WELL No. 1624.

Location: Santa Clara School, Andalucia and Cataluña Streets.
Depth, 445 feet.
Cased 320 feet.
Pumps 15 gallons per minute. Water stands at 6 inches below the surface.

Feet.
15. Brown sandy clay with shell fragments.
65. Basaltic sand and gravel.
77. Tuffaceous sandstone.
117. Gray tuff.
157. Basaltic sand and gravel like "65."
204. Rounded, coarse, and weathered basaltic sand and gravel.
316. Gray gravelly clay.
323. Gray tuff.
415. Coarse basaltic sand.

WELL No. 1689.

Location: O'Donnell Street.
Depth, 385 feet.
Cased 340 feet.
Pumps 60 gallons per minute. Water stands 3 feet below the surface.

Feet.	
0–100.	Gray tuffaceous clay.
100–115.	Sand and gravel (basalt and andesite porphyry).
115–168.	Gray tuff.
168–190.	Tuffaceous sand and fine gravel with a few shell fragments.
190–305.	Tuffaceous sand, fine grained.
305–337.	Tuffaceous sand, coarse grained.
337–342.	Tuffaceous gravel and sand, with shells (sample in collection).
342–355.	Tuffaceous sand.
355–365.	Cuttings from shale.
365–385.	Mixed coarse basaltic sand and gravel, mostly scoriaceous and vesicular.

WELL No. 2111.

Location: Bilibid Prison.
Depth, 650 feet.
Cased 480 feet and 100 feet.
Pumps 30 gallons per minute. Water stands 22 feet below the surface.
Determinations by L. F. Abad.

Feet.	
0– 30.	Clay and sand.
30– 60.	Fine gray sand with shells.
60– 90.	Tuffaceous clay.
90–120.	Basaltic sand.
120–150.	Dark gray calcareous clay with shell fragments.
180–210.	Tuffaceous sandstone.
210–270.	Tuff.
270–330.	Yellow clay with pebbles.
330–420.	Tuffaceous clay.
420–510.	Fine basaltic and tuffaceous sand.
510–540.	Fragments of vesicular basalt.
540–570.	Tuff with shell fragments.
570–600.	Tuffaceous sandstone.
600–650.	Fine sand with basaltic gravel.

WELL No. 2472.

Location: Bilibid Prison.
Depth, 800 feet.
Pumps 35 gallons per minute. Water stands 30 feet below the surface when pumping, and 20 feet below when not pumping.
Determinations by L. F. Abad.

Feet.	
0– 30.	Clay and sand. Salt water.
30– 40.	Medium sand.
40– 50.	Very fine tuffaceous sand. Fresh water.
50– 75.	Dark gray fossiliferous clay. Dry.
75– 90.	Basaltic gravel. Salt water.
90–105.	Dark brown arenaceous clay.
105–155.	Tuff.
155–195.	Coarse gravel.

Feet.
195–220. Clay and igneous pebbles.
220–300. Basaltic gravel.
300–310. Tuffaceous clay.
310–315. Tuff with fine gravel.
315–425. Gray fossiliferous clay.
425–430. Tuffaceous clay. Fresh water.
430–470. Tuffaceous sandstone.
470–500. Fine sand and tuffaceous clay.
500–510. Basaltic gravel.
510–520. Fine sand and tuffaceous clay.

WELL No. 1528.
Location: San Lazaro Hospital.
Depth, 880 feet.
Cased 880 feet.
Pumps 50 gallons per minute. Water stands 40 feet below the surface.
Determinations by L. A. Faustino.

Feet.
0– 35. Yellow pebbly clay.
35–135. Red plastic clay.
135–295. Gray sandstone.
295–311. Gray sticky clay with shells.
312–338. Yellow pebbly clay.
339–343. Pumiceous sand and gravel.
344–870. Yellow tuffaceous sand.

WELL No. 1479.
Location: San Lazaro.
Depth, 422 feet.
Cased 412 feet.
Pumps 60 gallons per minute. Water stands 4 feet below surface.
Determinations by L. A. Faustino.

Feet.
0– 70. Coarse igneous gravel.
70–240. Yellow gravelly clay and tuff.
240–250. Tuff.
250–270. Tuffaceous and basaltic sand.
270–330. Tuff with basaltic gravel.

WELL No. 1456.
Location: Magdalena Street, Trozo.
Depth, 847 feet.
Cased 802 feet.
Flows 4½ gallons per minute. Water rises 2 feet above the surface.
Determinations by L. A. Faustino.

Feet.
0– 15. Medium and fine sand.
16– 85. Gray tuff with shells.
86–100. Coarse igneous gravel.
110–126. Gray tuff with shells.

Feet.

126–242. Yellow tuff.
243–249. Gray sandstone.
250–325. Yellow gravelly clay.
326–372. Tuffaceous and basaltic sand.
373–393. Yellow gravelly clay.
394–445. Gray sandy tuff.
506–600. Gray gravelly clay.
601–606. Yellow sandy clay.
606–635. Basaltic gravel.
636–670. Gray plastic clay.
671–695. Yellow clay.
696–765. Light gray clay.
712–847. Yellow tuffaceous sand.

TONDO

WELL No. 1612.

Location: Gagalangin, Manila.
Depth, 390 feet.
Cased 341 feet.
Pumps 50 gallons per minute. Water stands 7 feet below the surface.

Feet.

0– 21. Gray clay with shells.
21– 45. Gravelly clay with fragments of shale.
45– 70. Black carbonaceous clay.
70– 90. Gray gravelly clay.
90–110. Basalt gravel.
110–140. Gray tuff.
140–318. Tuffaceous clay.
318–390. Tuffaceous sandstone.

WELL No. 1571.

Location: Manila Railroad Station.
Depth, 1,160 feet.
Cased 1,065 feet.
Pumps 65 gallons per minute. Water stands at 55 feet below the surface.

Feet.

0– 25. Gray pebbly clay.
26– 54. Brown sandy clay.
55– 95. Light gray tuffaceous clay.
96– 118. Sand and gravel, basalt abundant, some andesite and massive quartz.
119– 150. Black fine-grained sand, considerable magnetite grains.
151– 327. Sand and gravel, tuffaceous.
328– 352. Sharp-grained tuffaceous sand.
353– 445. Brown sandy clay, tuffaceous.
446– 460. Dark gray clay.
461– 575. Fine tuffaceous sand, magnetite quite abundant.
576– 580. Blue gravelly clay.

Feet.
581– 615. Fine tuffaceous sand.
616– 640. Gray tuffaceous clay and sand.
641– 655. Very fine sand.
656– 787. Gray tuff.
788– 807. Fine tuffaceous sand.
808– 954. Dark brown clay.
955–1080. Gray tuffaceous clay.
1081–1123. Very fine sand.

WELL No. 1674.

Location: Antonio Rivera Street.
Depth, 360 feet.
Cased 308 feet.
Pumps 30 gallons per minute. Water stands 14 feet below the surface.

Feet.
0– 30. Blue sandy clay with shells.
30– 85. Brown clay with gravel.
85–100. Fine gravel, mostly basaltic. Salt water.
100–130. Yellow sandy clay.
130–146. Tuffaceous sandstone. (Salt water.)
146–150. Coarse tuffaceous sand. (Salt water.)
150–195. Tuffaceous sandstone like "130–146."
195–210. Tuffaceous sand and gravel.
210–237. Tuffaceous sandstone like "130–146."
237–244. Tuffaceous sand.
244–250. Gray clay.
250–305. Tuffaceous sandstone like "130–146."
305–359. Coarse tuffaceous sand. Fresh water.

WELL No. 1929.

Location: Esguerra Street.
Depth, 390 feet.
Cased 321 feet with 6-inch pipe.
Pumps 30 gallons per minute. Water stands 16 feet below the surface.
Determinations by R. F. Abarquez.

Feet.
0– 20. Greenish somewhat consolidated silt with shells.
20– 38. Dense basaltic subangular fragments.
38– 95. Yellowish sandy and gravelly clay.
95–145. Gray silt with shell fragments.
145–190. Sand and gravel, mostly of dense basalt.
190–240. Yellowish gray volcanic sand, somewhat consolidated.
240–295. Gray clay loam with tiny shells.
295–337. Yellowish gray volcanic sand, somewhat consolidated.
337–385. Gray volcanic sand.
385–390. Black volcanic, mostly coarse, sand.

WELL No. 1894.

Location: Herbosa Street.
Depth, 460 feet.
Cased 400 feet with 6-inch pipe.
Pumps 50 gallons per minute. Water stands at 24 feet below the surface.
Determinations by R. F. Abarquez.

Feet.	
0– 20.	Black clay loam.
20– 95.	Yellow sandy and pebbly clay.
95–110.	Black clay loam with few shell fragments.
110–136.	Gray pumiceous sand.
136–159.	Coarse gravel.
159–233.	Tuff.
233–251.	Volcanic sand.
251–274.	Yellow gravelly clay.
274–396.	Tuff.
396–460.	Black volcanic sand.

WELL-JOB No. 14878.

Location: Moriones Street.
Depth, 851 feet.
Cased 625 feet.
Pumps 20 gallons per minute. Flows 5 gallons per minute. Water rises 2 feet above the surface.
Determinations by L. A. Faustino.

Feet.	
0–740.	No samples.
740–760.	Tuffaceous sand.
760–780.	Gray tuff.
780–800.	Tuffaceous sand.
820–840.	Tuff.
840–851.	Tuffaceous sand.

ILLUSTRATIONS

PLATE 1

Artesian well in Pandacan, near the corner of Jesus and Narciso Streets. (Photograph by the Bureau of Public Works.)

PLATE 2

Artesian well near San Lazaro market. (Photograph by the Bureau of Public Works.)

PLATE 3

Artesian well at Plaza Miranda, Quiapo. (Photograph by the Bureau of Public Works.)

TEXT FIGURES

FIG. 1. Manila and neighboring towns. (Based on Coast and Geodetic Survey map. Drawn in the division of mines, Bureau of Science.)

2. Sections of wells in Manila. (Drawn in the division of mines, Bureau of Science.)

3. Geologic section east and west across Manila and vicinity, diagrammatic; showing artesian conditions; *a*, alluvium; *b*, tuff; *c*, impervious material. (Drawn in the division of mines, Bureau of Science.)

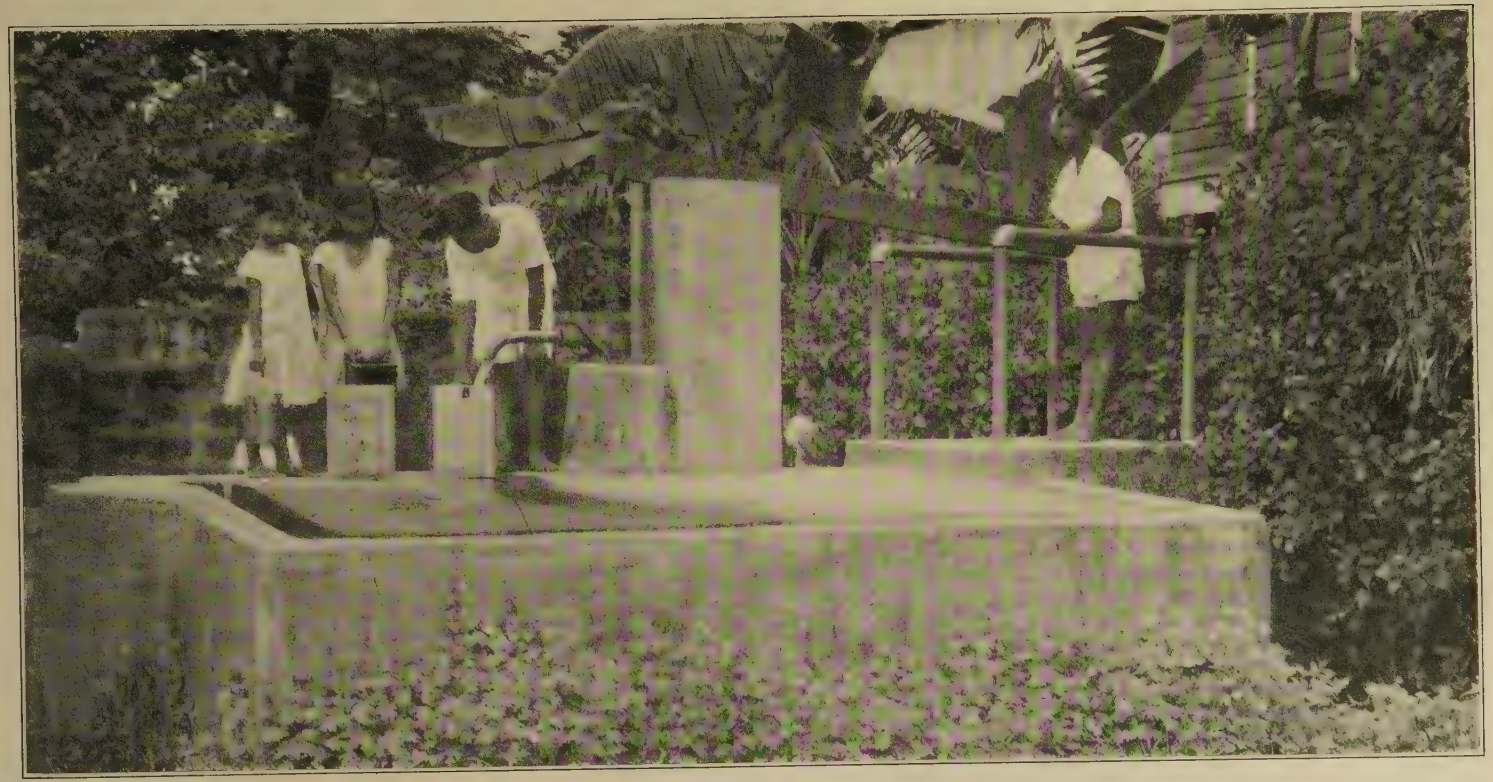

PLATE 1. ARTESIAN WELL IN PANDACAN.

PLATE 2. ARTESIAN WELL NEAR SAN LAZARO MARKET.

PLATE 3. ARTESIAN WELL AT PLAZA MIRANDA, QUIAPO.

ARTESIAN-WELL WATERS IN MANILA AND NEIGHBORING MUNICIPALITIES

By R. H. Aguilar and Lourdes Ocampo
Of the Bureau of Science, Manila

ONE PLATE

A great number of the inhabitants of the City of Manila and the majority of those in the neighboring municipalities obtain their drinking water from artesian wells. These are conveniently distributed so as to be accessible to the greatest number of people.

In previous years the first artesian waters were looked upon with suspicion [1] because the people were accustomed to drinking surface waters; but now, surface waters are almost completely abandoned for artesian waters, and even in the City of Manila where the city water is constantly under chemical and bacteriological control [2] a great proportion of the people prefer to use artesian waters for drinking purposes.

The first two artesian wells drilled for the Insular Government in Manila [3] were those located on Engineer Island and at Singalong Agricultural Experimental Station. The first was drilled by the Bureau of Coast Guard and Transportation and the second by the Bureau of Engineering. The work was performed in 1904. In the succeeding years more wells were drilled in the provinces. The satisfactory results observed by the people from the use of artesian waters, especially from the hygienic point of view,[4] caused many municipal councils to pass resolutions requesting the drilling of wells in their municipal-

[1] Heise, G. W., and A. S. Behrman, Philippine Water Supplies, Manila, Bu. Sci. Mon. 11 (1918) 11.

[2] Heise, G. W., Philip. Journ. Sci. § A 11 (1916) 1; and Taylor, Edward, Philip. Journ. Sci. 27 (1925) 297.

[3] Report U. S. Bur. of Eng. fiscal year ending June 30, 1905. Washington (1906) 174.

[4] Cox, A, J., G. W. Heise, and V. Q. Gana, Philip. Journ. Sci. § A 9 (1914) 275.

[5] Bur. of Pub. Works Annual Reports fiscal year ending June 30, 1907–1908, 1909, and 1910, Manila (1908) 33 and (1910) 28.

ities.[5] For similar reasons the municipal council of the City of Manila voted funds for the installation of artesian wells at convenient places in the city. The Bureau of Public Works completed the drilling of the first wells in 1919.[6] In the following years, more wells were drilled, and at present there are several artesian wells in every district within the city limits.

In view of the many requests for information, frequently received at the Bureau of Science regarding the properties of the waters from these wells and those in the neighboring municipalities, this work was undertaken for the purpose of gathering up-to-date data on which to base opinions on the quality of the waters, from the hygienic standpoint, and on their relative general characteristics and therapeutic values.

SCOPE OF THE WORK

A large proportion of the public artesian wells now in operation within the city limits and those in the nearby municipalities were included in this study. The work as outlined comprises the collection of samples and the chemical analysis of the samples. The temperature of the air and that of the water, the popularity of the well, judged from the number of persons using it, and the rate of flow were also noted. The average temperature of the waters is slightly higher than the temperature of the air.

GENERAL PLAN AND METHODS OF WORK

Eighty-two of the eighty-four wells examined are pumping wells, and two are flowing wells. The water was kept flowing for at least twenty minutes, measuring at the same time the rate of flow by means of a calibrated container, before samples were collected. For this purpose 4-liter bottles were used, filling them completely to the stopper. As soon as the specimens arrived at the laboratory, almost always within forty-five minutes after collection, the acidity, alkalinity, and nitrate determinations were made. The standard methods for the examination of water and sewage by the American Public Health Association [7] were strictly followed in the chemical examination of the water samples.

[6] Bur. of Pub. Works, Quarterly Bull. 28 (1920) 6.

[7] Standard Methods of Water Analysis, Am. Pub. Health Ass., New York (1925).

ANALYTICAL DATA

In the tabulation of analytical data, both the ionic form and the combined form of stating results were adopted. The statement in ionic form enables the reader to compare the mineral composition of these waters with the mineral composition of those in the United States, because the same form of statement is employed by the United States Geological Survey [8] in reporting mineral analyses of waters. On the other hand, the greater proportion of the local medical practitioners and health officers, who are the ones usually consulted in regard to the mineral quality of the waters and their suitability for drinking uses, are more familiar with the combined form than with the ionic form.

There is a great variety of methods of reporting results of analyses in the combined form. Dole [9] mentions several references to directions given by various authors.[10] A recent publication by Thresh and Beale [11] gives a method which, according to them, in practice works out more in accordance with the order of probability, and is based upon a list of salts that may enter into solution in natural waters in the order of their insolubility as given by Bunsen in his "Instruction für die Ausführung der vom Grossherzogl. Bad. Ministerium des Innern angeordneten chemischen Untersuchung der Badischen Mineral Wasser."

Of the various methods of combining the basic and acid ions, the one followed by Haywood and Smith [12] in reporting the analyses of the mineral waters in the United States was adopted for convenience. According to this method, the order of cal-

[8] U. S. Geological Survey, Water-Supply Papers.

[9] U. S. Geol. Surv. Water-Supply Paper 236 (1909) 40.

[10] (*a*) Walter, G., und A. Gärtner, Tiemann–Gartner's Handbuch der Untersuchung und Beurtheilung der Wässer, Braunschweig (1895) 357. (*b*) Wankling, J. A. and E. T. Chapman, Water-Analysis, 10th ed. Kegan Paul, Trench, Trübner and Co. Ltd., London (1896) 149. (*c*) Stillman, T. B., Engineering Chemistry, 3d ed. Chem. Pub. Co., Gaston, Pa. (1905) 47. (*d*) Fresenius, C. R., Quantitative Chemical Analysis, edited by O. P. Allen and S. W. Johnson. John Wiley and Sons, New York (1900) 674.

[11] The Examination of Waters and Water Supplies, 3d. ed. J. and A. Churchill, London (1925) 349.

[12] U. S. Dept. Agr. Bur. Chem. Bull. 91 (1905) 17.

culating the "hypothetical" combinations of the basic and acid ions is as follows:

Sodium is joined to nitrous and nitric acid, potassium to iodin and bromin, calcium to phosphoric acid, and sodium to metaboric acid. The residual basic ions are then assigned in the following order—ammonium, lithium, potassium, sodium, magnesium, calcium, manganese, iron and aluminium—to the residual acid ions in the following order—chlorin, sulphuric acid ion, carbonic acid ion and bicarbonic acid ion. In case the bicarbonic acid ion is not present in sufficient quantities to join with all the calcium, the residual calcium is joined to silica to form calcium silicate, and manganese, iron, and aluminium are calculated to the oxides Mn_3O_4, Fe_2O_3, and Al_2O_3, respectively.

After reading the various references on this subject, one is led to the conclusion that the statement of results in combinations has to be necessarily of a hypothetical nature. It is for this reason, no doubt, that different chemists combine the ions following arbitrary rules and methods which at the time may appear reasonable or advisable, and the result, as Clarke [13] has so aptly stated, "is a meaningless chaos of assumptions and uncertainties." It is apparent, therefore, that there must not be attached much significance to the hypothetical combinations adopted. They are here given to enable those that are accustomed to this form of report to interpret the qualities of the waters from the chemical results. After all, whether the analysis is given in ionic form or combined form, the substances present in predominating quantities will be in evidence and will determine the chemical character of the water.

BASIC CONSIDERATIONS IN DETERMINING THE QUALITY OF A WATER

Statements given in this work regarding the chemical qualities of waters used for drinking purposes are based upon the mineral constituents. No reference is given to the sanitary character of the waters from the chemical standpoint, because the usual analyses for free and albuminoid ammonia, nitrites and oxygen consumed, to determine pollution by disease-producing bacteria have been purposely left out, as unnecessary, under present conditions.

In this connection, Stephenson, Logan, and Waring [14] point out that in the case of deep wells, "the possibility of pollution

[13] Bull. U. S. Geol. Surv. 330 (1908) 54.

[14] U. S. Geol. Surv. Water-Supply Paper 576 (1928) 23.

can best be determined by inspection of the surroundings. Surface waters, shallow wells, and many springs require special care to prevent contamination. Deep wells are in general safer and are very rarely contaminated except by surface waters that may enter through defective casings." Contamination of this nature is detected by bacteriological examination supplemented with tests to determine any change in the mineral constituents. Thresh and Beale [15] are also of the opinion that the common practice of judging the purity of waters for human consumption on the basis of their content of nitrogen and oxygen consumed is not reliable. The following quotation is from Thresh and Beale:

> It must also be remembered that the term [pure water or wholesome water] originated before bacteria were thought of in connection with water, and when impurities were chiefly connected with water yielding excessive quantities of free or albuminoid ammonia, or of organic carbon or nitrogen. * * * Since the discovery of bacteria and the general recognition of the fact that they are the chief causes of unwholesomeness in water, our increasing knowledge of the constituents of water leads us to lay less and less stress upon the ammonias, carbon and nitrogen, as the bodies yielding these may be quite as harmless as chlorides or nitrates; consequently we find Sir A. Houston [16] defining a pure and wholesome water in a way which ignores this organic matter altogether.

Heise and Behrman,[17] in their work on Philippine water supplies, have already discussed the status of nitrogen determination in waters. After citing the experiences of Barnard [18] who, working on river waters, found out that free and albuminoid ammonia generally depend more on low and high water, temperature, and normal vegetable growth than upon pollution, they themselves made the following concluding remarks:

> Since the nitrogen content of deep wells is almost sure to be misleading, since simple determinations are of doubtful value, and since the nitrogen in its various forms can be determined accurately only on fresh samples of water, the nitrates, nitrites, and free and albuminoid ammonia determination may be omitted for all but exceptional cases.

In the tables, however, the test for nitrates was included to make this work comparable with similar works published by the United States Geological Survey.

[15] The Examination of Waters and Water Supplies, 3d ed. J. and A. Churchill, London (1925) 142.

[16] Lancet 1 (January 27, 1923).

[17] Philippine Water Supplies, Bu. Sci. Mon. 11 (1918) 107.

[18] Engineering Record (1913) 68, 297.

RELATION OF THE MINERAL CONSTITUENTS TO THE QUALITY OF THE WATERS

Perhaps one of the most difficult problems of a water chemist is to establish chemical standards on which to base opinions on the quality of drinking waters. Chemically pure water, in the words of Sir A. Houston,[19] is one that does not contain saline constituents that are objectionable either in quality or in quantity, and contains only the merest traces of organic matter. Heise and Behrman [20] believe that the best water for human consumption is water that is as free as possible from organic matter and that contains only relatively small quantities of the normal mineral ingredients of natural waters. Ellis and Lee [21] seem to hold the same belief. They state that the lower waters are in mineral content the more acceptable they are as sources of supply.

The agreement on this point is apparent; that is, the least-mineralized waters are the best waters for human consumption. In regard to the maximum values for mineral tolerance, however, opinions are as variable as individual taste and idiosyncrasy. According to Cox, Heise, and Gana, [22] a water containing 1,000 parts per million mineral matter is liable to prove laxative. A water containing 1,000 parts per million or more of total dissolved solids is classified by L. Grünhut [23] as mineral water, to distinguish it from the ordinary spring or well water. Buswell [24] is of the opinion that above 500 parts per million of mineral matter, the water has a salty or brackish taste detectible by most people. He observes, however, that he has known a public supply containing 2,000 parts per million of total solids. MacDougal [25] reports that the experience of the field expeditions from the desert laboratory of the Carnegie Institution demonstrates that saline or alkaline water containing as much as 2,500 milligrams per kilogram (2,500 parts per million) of dissolved salts may be used for periods of many days

[19] Lancet 1 (January 27, 1923) 193.

[20] Philippine Water Supplies, Bu. Sci. Mon. 11 (1918) 19.

[21] U. S. Geol. Surv. Water-Supply Paper 446 (1919) 226.

[22] Philip. Journ. Sci. § A 9 (1914) 381.

[23] Zeitschr. f. Balneol. (1912) 4, 433–6, Wasser u. Abwasser (1912) 5, 417–20, Pharm. Zentralh (1914) 55, 180.

[24] The Chemistry of Water and Sewage Treatment. The Chem. Cat. Co., N. Y. (1928) 71.

[25] Botanical Features of North American Deserts, Carnegie Institution Pub. 99 (1908) 109.

without serious discomfort, but if the proportion be increased to about 3,300 milligrams (3,300 parts per million) only hardened travellers may use the supply. Ellis and Lee [26] give the following ratings of waters by total solids. Low-mineralized waters, those containing 150 parts per million or less of total solids; moderately mineralized, between 150 and 500; highly mineralized, between 500 and 2,000; very highly mineralized, over 2,000.

Water supplies containing salt, as sodium chloride, from 500 to 700 parts per million (303 to 425 parts per million as chlorine) are not objectionable.[27] However, very much smaller quantities of calcium or magnesium chlorides would give the water a disagreeable taste. The American Water Works Association [28] gives as the limiting value for chlorides 250 parts per million (as chlorin).

In general, the sulphate (SO_4) content of deep-well waters in the Philippines is usually low. In this work only two specimens were found to contain above 200 parts per million sulphates (as SO_4). Magnesium and sodium in combination with the sulphate radical (SO_4) are cathartic. Seven hundred fifty milligrams magnesium per kilogram (750 parts per million) should be considered the maximum.[29] A water containing 42 grains crystallized magnesium sulphate ($MgSO_4.7H_2O$) and 42 grains British Pharmacopœia sodium sulphate ($Na_2SO_4.10H_2O$) per imperial gallon (equivalent to 234 and 179 parts per million SO_4, respectively) was pronounced unsuitable for domestic purposes [30] considering the amount that might be imbibed daily under tropical conditions and the prevalence of choleric diseases in the locality.

As to carbonates (as sodium carbonate) the amount present may vary from 20 or 30 parts to 500 parts of carbonate per million, the latter approaching in character some of the greatly vaunted "table" waters. In this connection, it is interesting to note that the greater proportion of the deep-well waters examined are soft alkaline waters, characterized by the predomi-

[26] U. S. Geol. Surv. Water-Supply Paper 446: 228.

[27] Thresh and Beale, The Examination of Waters and Water Supplies, 3d ed. J. and A. Churchill, London (1925) 206.

[28] Public Health Reports, No. 15, 40 (1925) 718.

[29] Dole, R. B., U. S. Geol. Surv. Mineral Resources of the U. S., Washington (1912) 1185–6.

[30] Thresh and Beale, The Examination of Waters and Water Supplies, 3d ed. J. and A. Churchill, London (1925) 148.

nance of sodium carbonates or bicarbonates. The following quotation from Thresh's report when he was medical officer of health for the County of Essex, England, will furnish some idea on the quality of sodium-carbonated or sodium-bicarbonated waters.[31]

> During the twenty years I have had these districts under observation there has never been the slightest reason to suspect that any of the above public water supplies were of anything but the most wholesome character. In many parts of the country we have small local supplies containing much more of the soda salts, and they are equally wholesome. The most popular table waters in the world are waters which contain larger quantities of the above soda salts, and a large proportion of the members of the medical profession regard them as more suitable for drinking purposes than ordinary hard waters.
>
> Natural seltzer water contains about 58 grains of carbonate of soda per [imp.] gallon [820 parts per million].
>
> Natural Apollinaris water contains about the same quantity.
>
> A natural water bottled at Peterborough contains about 40 grains [570 parts per million] of carbonate and 12¼ grains [175 parts per million] of sulphate of soda and is very highly spoken of by the "Lancet" (Feb. 1904) in whose laboratory the analysis was made.

In regard to the degree of hardness of waters, the English Parliament in a bill [32] decided that a water of about 22° (Clark) hardness (315 parts per million) should be softened; which is in accord with the belief of Permain and Moor [33] that a greater hardness than 300 parts per million is undesirable from the hygienic standpoint. Middleton's [34] limiting value is 350 parts per million. Chase,[35] studying the relation of hardness in water supply to public health, reached the conclusion that statistical evidence indicates no relation between hardness in drinking waters and death from disease of the arteries, kidneys, and bladder. The hardness of the waters studied ranges from 10 to 30 parts per million for soft waters, from 100 to 250 parts per million for hard waters. Meyers,[36] in his efforts to find the effect of hard water on growth, appearance, and general well being, performed a series of experiments on white mice, white rats, young rabbits, dogs, calves, and several groups of chicks. His findings were that animals develop better with the use of hard wa-

[31] Thresh and Beale, op. cit. 150.

[32] Thresh and Beale, op. cit. 152.

[33] Mason, W. P., Examination of Water. John Wiley and Sons, Inc., New York (1917) 34 and 35.

[34] Loc. cit.

[35] Journ. Am. Water Works Ass. 2 (1924) 873.

[36] Journ. Infec. Dis. 37 (1925) 13–34.

ter than with distilled water under several conditions. He used a very hard natural water, having a total hardness of 520 parts per million $CaCO_3$.

The following data taken from different publications will furnish an idea of the more or less arbitrary way waters are classified according to the degree of hardness.

Classification by Thresh and Beale.[37]

Less than 50, very soft.
50 to 100, fairly soft.
100 to 150, neither hard nor soft.
150 to 200, moderately hard.
200 to 300, hard.
300 and over, very hard.

Classification by Permain and Moore.[38]

30 to 50, very soft.
50 to 100, moderate.
100 to 300, hard.
300 and over, very hard.

Classification by Buswell.[39]

Less than 100, soft.
100 to 200, moderately hard.
200 to 500, hard.
500 and over, saline.

Baskerville.[40] Less than 50 parts per million, soft, above 100, hard; between 50 and 100, open to discussion and dependent upon local preferences.

CLASSIFICATION OF WATERS ON THE BASIS OF THE PREDOMINATING MINERAL CONSTITUENTS

In classifying the waters on the basis of their mineral constituents, the method adopted by Peale,[41] as modified by Haywood and Smith,[42] has been followed as the best adapted to our purpose. It was pointed out by Bartow, however, that these classifications and others of a similar nature are of limited value, since they refer to the kinds with no reference to the amounts of constituents, as Buswell [43] clearly illustrates in the following

[37] Waters and Water Supplies, J. and A. Churchill, London (1925) 214.
[38] Mason's Examination of Water 35.
[39] The Chemistry of Water and Sewage Treatment. The Chem. Cat. Co. Inc., New York (1928) 71.
[40] Municipal Chemistry. McGraw-Hill Book Co., New York (1911) 88.
[41] A System of Physiologic Therapeutics, edited by S. S. Cohen 9: 302.
[42] U. S. Bu. Chem. Bull. 91 (1905) 9.
[43] The Chemistry of Water and Sewage Treatment. The Chem. Cat. Co., N. Y. (1928) 71.

TABLE 1.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities.*

[Report of analysis in ionic form. Results in milligrams per liter.]

Tracing No.	Location.	Well No.	Depth of well; meters.	Date of collection of samples.	Capacity; liters per minute.	Total solids (at 180° C.).	Silica (SiO_2).	Iron (Fe).	Aluminium (Al).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).
1	2	3	4	5	6	7	8	9	10	11	12	13
	MANILA.			1929								
M-1	Santiago, near G. Tuason, Sampaloc	1921	160	July 23	29	215	28	0.03	0.62	1.7	tr	59
2	Plaza Guipit, Sampaloc			Sept. 11	31	250	30	0.11	0.77	2.6	tr	76.5
3	Plaza Moriones, Tondo		260	May 29	30	260	24	0.06	0.8	2	tr	84
4	Corner Victoria and Muralla Streets, Intramuros.	1939	223	May 20	30	275	26	0.44	1.6	2.9	tr	85
5	San Lazaro Hospital	1528	269	July 13		295	30	0.13	0.75	0.86	tr	95
6	Esguerra, between Yangco and Franco Streets, Tondo.	1929	119	July 22	35	305	34	0.07	0.8	1.7	tr	95
7	Santa Mesa Market, at Teresa Street	1505	170	July 11	24	315	40	0.06	0.8	3.4	tr	97
8	Estado Street, between Benavides and Magdalena.	1456		June 8	8	350	54	0.16	0.94	1.1	tr	115
9	San Lazaro Market, Blumentritt Street	1479	129	June 27	33	350	65	0.07	1	3.4	tr	112
10	Santa Clara School, Andalucia Street	1629	136	July 18	27	370	74	0.11	0.76	1.4	tr	105
11	Antonio Rivera, near Tayuman	1674	122	July 20	34	370	70	0.07	0.58	1.7	tr	102
12	Manrique Street, in front of Sampaloc Church	1665	136	June 13	26	375	50	0.06	0.81	3.4	tr	123
13	Jesus and Narciso Streets, Pandacan	1433	144	June 25	34	395	64	0.06	1	3.4	tr	116
14	Plaza Miranda, at Quiapo Church	1446	153	June 4	34	485	60	0.12	1.2	3.7	tr	144
15	O'Donnell, between Lope de Vega and Zurbaran.	1689	118	July 6	29	545	61	0.05	1	10	tr	175
16	Anak Bayan, Paco	1599	154	July 9	33	545	69	0.14	1.2	4	tr	185
17	Del Pan, San Nicolas	1630	92	July 19	45	595	83	0.16	0.72	8.3	2.7	175
18	Paco Market, Dart and Herran Streets	1675	101	June 21	36	625	77	0.14	1.2	8.6	4	198
19	Santa Ana Market, Calderon Street	1396	166	June 11	28	755	57	0.11	0.98	10	tr	243

20	Engineer Island	1	178	Oct. 8	--------	880	66	0.06	0.8	16	tr	279.6
21	Plaza de la Virgen, Pandacan	2425	205	Aug. 12	30	965	55	0.42	0.95	19	tr	292
22	Malate Market, Leveriza Street	1658	198	May 17	34	1,145	68	0.12	1.2	18	tr	309
	CALOOCAN.											
C-1	Novaliches Road, between kms 10 and 11	--------	--------	Sept. 19	30	180	23	0.06	0.81	5.4	tr	55.5
2	Balon Bato, Novaliches Road, between kms 9 and 10.	2487	150	Sept. 24	32	180	26	0.05	0.81	2.8	tr	59
3	Cangcong Barrio, Novaliches Road, between kms 8 and 9.	2576	107	Sept. 27	63	215	37	0.12	0.97	3.7	2.1	62.5
4	Rizal Avenue extension, between kms 6 and 7	1916	151	July 3	30	220	20	0.02	0.41	5.2	tr	75
5	Balintawak, near km 9	895	126	Oct. 1	39	225	32	0.16	0.94	4	tr	69.8
6	Novaliches Road, between kms 17 and 18	2505	107	June 18	34	235	47	0.06	0.8	1.1	tr	78
7	Novaliches Plaza, between kms 17 and 18	916	102	Aug. 3	28	235	42	0.04	0.6	0.57	tr	83
8	San Bartolome, Novaliches Road, between kms 16 and 17.	925	100	Aug. 8	26	270	39	1.6	1.4	27	9.7	49
9	Baisa Barrio, Balintawak, between kms 12 and 13.	950	107	Aug. 29	31	270	54	0.14	0.95	23	5	47
10	Mabini Street, near Sañgandaan	1472	123	June 6	34	275	71	0.08	0.78	12	3.2	69
11	Dulong Calzada, between kms 8 and 9	1867	145	July 25	27	275	66	0.04	0.61	3.4	tr	62
12	Baisa Barrio, Balintawak, between kms 11 and 12.	--------	--------	Sept. 5	18	280	105	0.68	1.4	22	7.1	31
13	Novaliches Road, between kms 14 and 15	938	84	Aug. 20	25	300	75	0.6	1	36	16	30.5
14	A. Mabini, between kms 8 and 9	2478	124	Aug. 27	29	310	85	0.08	0.79	12	2.9	67
15	Sampalucan, A. Mabini, between kms 7 and 8.	695	191	July 16	30	320	33	0.07	0.58	2	tr	102
16	Talipapa, Balintawak, between kms 13 and 14	2571	116	Aug. 24	27	330	94	0.32	1	36	16	34
17	Caloocan Plaza, near the municipal building	105	218	Sept. 17	50	330	43	0.08	0.58	3.4	tr	110
18	A. Mabini, North Road, near km 9	683	205	Sept. 28	13	330	63	0.22	0.90	4.9	1.4	100
19	A. Mabini, North Road, near km 7	2469	84	Oct. 3	37	335	76	0.1	0.77	4.6	2.8	91
	SAN JUAN DEL MONTE.											
SJ-1	Mariquina Road, between kms 7 and 8	2354	157	Sept. 20	29	245	31	0.09	0.78	5.4	tr	74
2	Corner Blumentritt and Bonifacio	--------	--------	Aug. 28	8	290	74	0.17	0.93	9.4	1.8	70
3	Market place	878	101	May 23	21	295	60	0.14	0.74	2.9	tr	92.4
4	Santa Lucia Barrio	1806	72	July 31	27	295	78	0.07	0.8	16	6.8	58

TABLE 1.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities*—Continued.

Tracing No.	Location.	Well No.	Depth of well; meters.	Date of collection of samples.	Capacity; liters per minute.	Total solids (at 180° C.).	Silica (SiO_2).	Iron (Fe).	Aluminium (Al).	Calcium (Ca).	Magnesium (Mg).	Sodium (Na).
1	2	3	4	5	6	7	8	9	10	11	12	13
	SAN JUAN DEL MONTE—Continued			1929								
5	Rizal Street, near Burgos	------	------	Sept. 9	30	295	72	0.08	0.79	8.2	2.4	71
6	Ermitaño Barrio, East Street	1744	55	Oct. 4	49	295	59	0.08	0.79	3.7	tr	80
7	Mariquina Road, Ermitaño Barrio, between kms 8 and 9.	------	------	July 2	34	300	62	0.1	1.2	8.6	tr	88
8	Broadway, near First Street, New Manila	------	------	Sept. 23	14	300	59	0.02	0.62	7.7	tr	83.5
9	Cubao Barrio, Mariquina Road, between kms 10 and 11.	1812	150	Sept. 13	31	305	79	0.32	1	17	5.2	65
10	Ortega Street Addition	2334	93	Aug. 2	36	320	72	0.04	0.6	2.3	tr	95
11	San Pedro Street near km 6, Mariquina Road	1780	93	Oct. 2	33	390	86	0.22	0.89	6.4	3.1	96
	SAN FELIPE NERI.											
SF–1	Hagdaan Bato, Bonifacio Street	2535	120	Oct. 8	34	275	67	0.24	1.1	11	4	60
2	T. Kalazan, near river	1636	47	Sept. 26	38	295	78	0.29	0.84	27	9.9	41
3	Lamayan, corner Rizal and Vergara	872	110	Oct. 1	35	300	59	0.08	0.78	4.3	tr	95
4	Blumentritt, between municipal building and school.	859	63	Aug. 1	23	305	86	0.28	1.1	26	8.5	43
5	Mabini Street	1840	126	Sept. 10	28	305	61	0.11	0.77	2.3	tr	86
6	Zanega Barrio	2527	96	Aug. 6	38	310	69	0.15	0.74	5.2	tr	75
7	Jolo Barrio	2375	90	Aug. 19	26	310	61	0.11	0.76	0.86	tr	97
8	Barranca	1664	109	Sept. 14	30	315	71	0.1	0.56	17.5	4.8	68
9	Hagdaan Bato, corner A. Luna and Bonifacio	863	60	Aug. 21	27	325	100	0.12	0.97	34	15	26.6
10	Kalentong Street, between kms 9 and 10	1832	46	Sept. 7	31	335	90	0.19	0.71	22	8.5	58.5
11	Jolo Barrio, at J. Coronado	1712	106	Aug. 23	33	345	75	0.21	0.9	4.3	tr	94

12	Blumentritt Street, in front of market	798	270	July 30	24	495	63	0.27	1.1	5.4	tr	140
13	Lamayan Barrio, Segura and Rizal Streets	2520	130	Sept. 25	33	685	53	0.19	0.92	10	tr	204
	SAN PEDRO MAKATI.											
SP-1	Guadalupe, McKinley Road, kms 7 and 8	1610	129	Aug. 7	34	225	42	0.1	0.77	4.9	tr	65
2	McKinley Road, between kms 6 and 7	802	108	July 27	33	230	37	0.08	0.79	0.86	tr	68
3	Guadalupe, Ninety-sixth Street	1622	84	Aug. 22	18	280	54	0.36	1.4	2	tr	80
4	J. Rizal and P. P. Roxas	258	171	June 29	31	285	50	0.03	0.4	5.7	tr	93
5	Olimpia Barrio, J. B. Roxas Street	786	129	Sept. 26	17	300	42	0.22	1.1	5.7	3.1	82.5
6	Bonifacio Street, 1 km east of the municipal building.	2052	104	Oct. 3	36	305	52	0.14	0.74	1.7	tr	90
7	E. Zobel Street	814	124	Oct. 7	30	360	75	0.72	1.4	16	8.7	80
8	Cristal Barrio, in front of chapel	1995	220	Oct. 5	36	365	44	0.08	0.58	4.9	tr	100
9	Masilang Barrio, Soliman, near Comercio	841	128	Sept. 24	28	390	95	0.46	1.1	24	11	76.3
10	Tejeron Barrio, McKinley Road, kms 4 and 5	2013	109	Sept. 18	32	410	50	0.14	0.74	0.86	tr	129
11	Culiculi Barrio, near Batangas railroad track	1445	55	Aug. 10	33	415	98	4.8	1.9	29	12	75
12	Guadalupe, in front of Dapitan Street	1601	130	Sept. 6	22	420	85	0.27	0.64	23	4.3	94
	PASAY.											
P-1	San Roque Barrio, corner Tolentino and Protacio.	732	69	Aug. 30	31	415	94	1.7	1.2	34	23	50
2	Malibay Barrio, corner of Jose Street, near chapel.	877	149	Aug. 26	29	425	115	0.88	1	33	12	74
3	Santol Barrio, corner Protacio and Decena	765	179	Sept. 12	29	535	87	0.25	0.87	7.7	3.3	149
4	Leveriza, near Villaruel			July 29	29	585	80	0.12	0.76	5.4	3.8	172
5	Corner Tolentino and Aurora	768	108	Aug. 5	35	730	91	4.3	1.8	27	17	173
6	Zamora Street, corner of Apelo Cruz, Tabon	444	92	July 26	33	935	89	1.5	1.6	56	22	215
7	Tambo Barrio, at Camp Claudio			May 18	37	1,245	75	0.32	1.5	17	6.5	332

TABLE 1.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities*—Continued.

Tracing No.	Location.	Potassium (K).	Carbonate radical (CO_3).	Bicarbonate radical (NCO_3).	Sulphate radical (SO_4).	Chloride radical (Cl).	Nitrate radical (NO_3).	Free carbondioxide (CO_2).	Total hardness (as $CaCO_3$).	Chemical character.
1	2	14	15	16	17	18	19	20	21	22
	MANILA.									
M–1	Santiago, near G. Tuason, Sampaloc	18	18.7	43	29	35	0.2		4.3	$Na–HCO_3$.
2	Plaza Guipit, Sampaloc	13	21.5	91	36	30	0.09		6.4	$Na–HCO_3$.
M–3	Plaza Moriones, Tondo	9.4	20	81	44	38	0.07		5	$Na–HCO_3$.
4	Corner Victoria and Muralla Streets, Intramuros	14	23	28	73	41	0.15		7.2	$Na–SO_4$.
5	San Lazaro Hospital	3.6	23	54	66	42			2.1	$Na–SO_4$.
6	Esguerra, between Yangco and Franco Streets, Tondo	20	8.5	20.6	16	26	0.09		4.3	$Na–HCO_3$.
7	Santa Mesa Market, at Teresa Street	9.4	12	34	70	66	0.07		8.6	$Na–SO_4$.
8	Estado Street, between Benavides and Magdalena	8.4	11	53	100	41	0.07		2.9	$Na–SO_4$.
9	San Lazaro Market, Blumentritt Street	4.6	15	156	31	45	0.15		8.6	$Na–HCO_3$.
10	Santa Clara School, Andalucia Street	11	27	66	39	75	0.18		3.6	Na–Cl.
11	Antonio Rivera, near Tayuman	17	41	40	43	72	0.22		4.3	Na–Cl.
12	Manrique Street, in front of Sampaloc Church	6.8	15	95	54	78	0.09		8.6	$Na–HCO_3$.
13	Jesus and Narciso Streets, Pandacan	15	24	66	60	81	0.11		8.6	Na–Cl.
14	Plaza Miranda, at Quiapo Church	17	3.8	70	93	130	0.07		9.3	Na–Cl.
15	O'Donnell, between Lope de Vega and Zurbaran	15	12	117	41	170	0.14		25	Na–Cl.
16	Anak Bayan, Paco	16	7.3	330	60	42	0.11		10	$Na–HCO_3$.
17	Del Pan, San Nicolas	35	1.2	314	10	125	0.15		32	$Na–HCO_3$.
18	Paco Market, Dart and Herran Streets	23		470	8.6	73	0.18	4.3	36	$Na–HCO_3$.
19	Santa Ana Market, Calderon Street	16	7	112	145	225	0.06		25	Na–Cl.
20	Engineer Island	36.2	14	23	77	390	0.13		39	Na–Cl.
21	Plaza de la Virgen, Pandacan	35		155	250	240	0.14	2	46	$Na–SO_4$.
22	Malate Market, Leveriza Street	96	5.1	55	225	390	0.06		46	Na–Cl.

	CALOOCAN									
C–1	Novaliches Road, between kms 10 and 11	6.2	18.7	125	0.83	5	0.07	-------	14	$Na–HCO_3$.
2	Balon Bato, Novaliches Road, between kms 9 and 10	7.2	24.9	111	2.5	6.5	0.13	-------	7.1	$Na–HCO_3$.
3	Cangcong Barrio, Novaliches Road, between kms 8 and 9	8.8	16.4	135	13	8	0.09	-------	18	$Na–HCO_3$.
4	Rizal Avenue extension, between kms 6 and 7	2.7	17	156	7.4	9.6	0.09	-------	13	$Na–HCO_3$.
5	Balintawak, near km 9	11	19.8	135	16	10	0.11	-------	10	$Na–HCO_3$.
6	Novaliches Road, between kms 17 and 18	4.5	28	149	3.1	4	0.06	-------	2.9	$Na–HCO_3$.
7	Novaliches Plaza, between kms 17 and 18	5.4	28.3	145	2.8	4.8	0.62	-------	1.4	$Na–HCO_3$.
8	San Bartolome, Novaliches Road, between kms 16 and 17	8.5	-------	260	tr	7.7	0.49	2	110	$Na–HCO_3$.
9	Baisa Barrio, Balintawak, between kms 12 and 13	19	-------	238	do	6.7	0.53	2	77	$Na–HCO_3$.
10	Mabini Street, near Sañgandaan	7.3	0.6	205	5.9	13	0.04	-------	44	$Na–HCO_3$.
11	Dulong Calzada, between kms 8 and 9	26	13	148	15.7	12	0.09	-------	8.6	$Na–HCO_3$.
12	Baisa Barrio, Balintawak, between kms 11 and 12	10.5	-------	180	3.6	9.6	0.11	29	85	$Na–HCO_3$.
13	Novaliches Road, between kms 14 and 15	6.4	-------	270	tr	5.8	0.09	4	160	$Ca–HCO_3$.
14	A. Mabini, between kms 8 and 9	13	1.9	205	8.6	17	0.09	-------	42	$Na–HCO_3$.
15	Sampalucan, A. Mabini, between kms 7 and 8	15.5	15	210	27	14	0.14	-------	5	$Na–HCO_3$.
16	Talipapa, Balintawak, between kms 13 and 14	7.4	-------	280	tr	6.7	0.09	5.9	155	$Ca–HCO_3$.
17	Caloocan Plaza, near the municipal building	15.5	14.1	230	21	14	0.11	-------	8.6	$Na–HCO_3$.
18	A. Mabini, North Road, near km 9	11.5	16.4	220	19	13	0.09	-------	18	$Na–HCO_3$.
19	A. Mabini, North Road, near km 7	14	-------	250	6.6	18	0.09	2	23	$Na–HCO_3$.
	SAN JUAN DEL MONTE.									
SJ–1	Mariquina Road, between kms 7 and 8	6	15.3	100	33	28	0.09	-------	14	$Na–HCO_3$.
2	Corner Blumentritt and Bonifacio	12.5	5.6	210	4.8	7.7	0.15	-------	31	$Na–HCO_3$.
3	Market place	6.8	27	173	8.1	14	0.16	-------	7.2	$Na–HCO_3$.
4	Santa Lucia Barrio	8	1.2	228	4.9	7.7	0.19	-------	67	$Na–HCO_3$.
5	Rizal Street, near Burgos	14.5	4.8	215	6.1	8.6	0.07	-------	30	$Na–HCO_3$.
6	Ermitaño Barrio, East Street	13	13	179	11	14	0.07	-------	9.2	$Na–HCO_3$.
7	Mariquina Road, Ermitaño Barrio, between kms 8 and 9	12	1.2	222	6.6	11	0.58	-------	21	$Na–HCO_3$.
8	Broadway, near First Street, New Manila	12.5	4.8	235	4.4	8.1	0.04	-------	19	$Na–HCO_3$.
9	Cubao Barrio, Mariquina Road, between kms 10 and 11	9	2.4	245	1.5	7.0	0.15	-------	63	$Na–HCO_3$.
10	Ortega Street addition	12	18.7	205	7.1	11	0.09	-------	5.7	$Na–HCO_3$.
11	San Pedro Street, near km 6, Mariquina Road	30	-------	285	3.6	27	0.07	4	16	$Na–HCO_3$.

TABLE 1.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities*—Continued.

Tracing No.	Location.	Potassium (K).	Carbonate radical (CO_3).	Bicarbonate radical (NCO_3).	Sulphate radical (SO_4).	Chloride radical (Cl).	Nitrate radical (NO_3).	Free carbon dioxide (CO_2).	Total hardness (as $CaCO_3$).	Chemical character.
1	2	14	15	16	17	18	19	20	21	22
	SAN FELIPE NERI.									
SF–1	Hagdaan Bato, Bonifacio Street	16.5	-------	210	6.9	10	0.07	2	43	$Na–HCO_3$.
2	T. Kalazan, near river	8.4	-------	230	0.82	7	0.09	4	110	$Na–HCO_3$.
3	Lamayan, corner Rizal and Vergara	7.5	17.5	205	6.1	12	0.07	-------	11	$Na–HCO_3$.
4	Blumentritt, between municipal building and school	11	-------	235	tr	9.6	0.20	5.9	100	$Na–HCO_3$.
5	Mabini Street	14	15.3	175	13	20	0.14	-------	5.7	$Na–HCO_3$.
6	Zanega Barrio	24	3.6	205	7.9	16	2.21	-------	13	$Na–HCO_3$.
7	Jolo Barrio	12	10.7	220	10.4	11	0.18	-------	2.1	$Na–HCO_3$.
8	Barranca	12.5	3.6	250	3.3	9	0.11	-------	63	$Na–HCO_3$.
9	Hagdaan Bato, corner A. Luna and Bonifacio	10	-------	212	1.8	27	5.31	19	150	$Ca–HCO_3$.
10	Kalentong Street, between kms 9 and 10	10.5	-------	260	3.3	9.6	0.04	3	91	$Na–HCO_3$.
11	Jolo Barrio, at J. Coronado	12	28.4	110	29	43	0.11	-------	11	$Na–HCO_3$.
12	Blumentritt Street, in front of market	18	13	59	150	77	0.09	-------	14	$Na–SO_4$.
13	Lamayan Barrio, Segura and Rizal Streets	42	7.4	155	20	255	0.07	-------	25	Na–Cl.
	SAN PEDRO MAKATI.									
SP–1	Guadalupe, McKinley Road, kms 7 and 8	13	18.7	125	10	12	0.44	-------	12	$Na–HCO_3$
2	McKinley Road, between kms 6 and 7	15.4	16	127	16	14	0.2	-------	2.1	$Na–HCO_3$.
3	Guadalupe, Ninety-sixth Street	14	14.1	170	15	13	0.27	-------	5	$Na–HCO_3$.
4	J. Rizal and P. P. Roxas	7.3	20	54	48	41	0.09	-------	14	$Na–HCO_3$.
5	Olimpia Barrio, J. B. Roxas Street	20	9	180	16	37	0.07	-------	27	$Na–HCO_3$.
6	Bonifacio Street, 1 km east of the municipal building	22.6	10.7	222	6.1	16	0.04	-------	4.3	$Na–HCO_3$.
7	E. Zobel Street	15.5	-------	301	2.5	14	tr	5	75	$Na–HCO_3$.
8	Cristal Barrio, in front of chapel	27	17	104	55	66	0.07	-------	12	$Na–HCO_3$.
9	Masilang Barrio, Soliman, near Comercio	6.9	-------	310	7.6	12	0.11	11	105	$Na–HCO_3$.

10	Tejeron Barrio, McKinley Road, kms 4 and 5	18	7.3	180	40	74	0.07		2.1	$Na-HCO_3$.
11	Culiculi Barrio, near Batangas railroad track	10.5		347	tr	9.6	0.24	18	120	$Na-HCO_3$.
12	Guadalupe, in front of Dapitan Street	19		325	13	17.5	0.11	4	75	$Na-HCO_3$.
	PASAY.									
P–1	San Roque Barrio, corner Tolentino and Protacio	16		335	tr	23	0.11	25	180	$Na-HCO_3$.
2	Malibay Barrio, corner of Jose Street, near chapel	12		350	1.3	9.5	0.04	17	130	$Na-HCO_3$.
3	Santol Barrio, corner Protacio and Decena	25	4.8	310	50	52	0.14		33	$Na-HCO_3$.
4	Leveriza, near Villaruel	34	3.4	332	16	110	0.09		29	$Na-HCO_3$.
5	Corner Tolentino and Aurora	36		350	9.4	185	0.11	16	135	$Na-HCO_3$.
6	Zamora Street, corner of Apelo Cruz, Tabon	43		324	15	335	0.11	12	230	Na–Cl.
7	Tambo Barrio, at Camp Claudio	125		246	115	445	0.04	3.2	69	Na–Cl.

TABLE 2.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities.*

[Hypothetical form of combination. Results in milligrams per liter.]

Tracing No.	Location.	Potassium chloride (KCl).	Sodium chloride ($NaCl$).	Sodium sulphate (Na_2SO_4).	Sodium nitrate ($NaNO_3$).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).	Magnesium bicarbonate Mg-$(HCO_3)_2$.	Calcium bicarbonate Ca-$(HCO_3)_2$.	Sodium silicate (Na_2SiO_3).
1	2	2	3	4	5	6	7	8	9	10
	MANILA.									
M–1	Santiago, near G. Tuason, Sampaloc	34.3	30.9	42.8	0.274	33.1	59.2			6.4
2	Plaza Guipit, Sampaloc	24.8	30.1	53.2	0.123	37.7	114.5		10.5	
3	Plaza Moriones, Tondo	17.9	48.7	65.1	0.096	35.3	103.7		8.2	
4	Corner Victoria and Muralla Streets, Intramuros	26.7	46.7	108.1	0.206	40.6	38.6			9.3
5	San Lazaro Hospital	6.9	63.8	97.7		40.6	74.6			
6	Esguerra, between Yangco and Franco Streets, Tondo	38.1	12.9	23.7	0.123	15.1	275.7		7.4	
7	Santa Mesa market, at Teresa Street	17.9	94.9	103.6	0.096	21.2	46.8			10.6
8	Estado Street, between Benavides and Magdalena	16	55.1	147.9	0.096	19.4	73			44.8
9	San Lazaro market, Blumentritt Street	8.8	67.3	45.9	0.206	26.5	215.3			

TABLE 2.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities*—Continued.

Tracing No.	Location.	Potassium chloride (KCl).	Sodium chloride ($NaCl$).	Sodium sulphate (Na_2SO_4).	Sodium nitrate ($NaNO_3$).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).	Magnesium bicarbonate $Mg(HCO_3)_2$.	Calcium bicarbonate $Ca(HCO_3)_2$.	Sodium silicate (Na_2SiO_3).
1	2	2	3	4	5	6	7	8	9	10
	MANILA—Continued.									
10	Santa Clara School, Andalucia Street	21.1	107.2	57.7	0.248	47.7	85.4	----------	5.6	----------
11	Antonio Rivera, near Tayuman	32.4	93.4	63.6	0.302	72.5	48.2	----------	6.7	----------
12	Manrique Street, in front of Sampaloc Church	12.9	118.5	79.9	0.123	26.5	130.8	----------	----------	8.2
13	Jesus and Narciso Streets, Pandacan	28.6	111.2	88.8	0.151	42.4	90.9	----------	----------	----------
14	Plaza Miranda, at Quiapo Church	32.4	189.1	137.6	0.096	6.7	80.7	tr	15.1	----------
15	O'Donnell, between Lope de Vega and Zurbaran	28.6	258.1	60.7	0.192	21.2	161.1	----------	----------	----------
16	Anak Bayan, Paco	30.5	45.4	88.8	0.151	12.9	454.4	----------	----------	21.8
17	Del Pan, San Nicolas	66.8	153.7	14.8	0.208	2.1	396.8	16.2	16.6	----------
18	Paco Market, Dart and Herran Streets	43.9	86.1	12.6	0.247	----------	584.1	24.1	34.6	----------
19	Santa Ana Market, Calderon Street	30.5	347.5	214.6	0.082	12.4	113.6	----------	39.5	----------
20	Engineer Island	69.1	589.1	113.9	0.178	24.7	----------	----------	30.5	----------
21	Plaza de la Virgen, Pandacan	66.8	343.7	370	0.192	----------	133.6	----------	77.1	----------
22	Malate Market, Leveriza Street	183	500	333	0.085	9.1	----------	----------	72.8	----------
	CALOOCAN.									
C-1	Novaliches Road, between kms 10 and 11	10.5	----------	1.5	0.096	33.1	149.8	----------	21.5	----------
2	Balon Bato, Novaliches Road, between kms 9 and 10	13.7	----------	3.7	0.178	44.1	141.3	----------	11.3	----------
3	Cangcong Barrio, Novaliches Road, between kms 8 and 9.	16.8	----------	19.2	0.123	29.3	159.7	12.6	11.3	----------
4	Rizal Avenue extension, between kms 6 and 7	5.1	11.9	10.9	0.124	30.1	194.1	----------	21.1	----------
5	Balintawak, near km 9	21	----------	23.7	0.154	35	169.3	----------	16.1	----------
6	Novaliches Road, between kms 17 and 18	8.6	----------	4.6	0.082	49.5	200.7	----------	4.4	----------
7	Novaliches Plaza, between kms 17 and 18	10.2	----------	4.1	0.850	50	199.7	----------	----------	14.1
8	San Bartolome, Novaliches Road, between kms 16 and 17.	16.2	----------	----------	0.672	----------	178.9	58.2	109.2	----------

9	Baisa Barrio, Balintawak, between kms 12 and 13	14.1			0.728		[b]201.5	30.1	93.1	
10	Mabini Street, near Sañgandaan	13.9	10.6	8.7	0.055	1.1	225.4	19.2	33.6	
11	Dulong Calzada, between kms 8 and 9	25.2		[a]28.5	0.123	23.1	189.8		13.5	
12	Baisa Barrio, Balintawak, between kms 11 and 12	20.1		5.3	0.151		106.3	42.5	89.1	
13	Novaliches Road, between kms 14 and 15	12.2			0.123		111.3	96.1	146.2	
14	A. Mabini, between kms 8 and 9	24.8	8.6	12.7	0.123	3.4	211.9	17.4	48.6	
15	Sampalucan, A. Mabini, between kms 7 and 8	29.5		40.1	0.192	26.5	280.6		8.1	
16	Talipapa, Balintawak, between kms 13 and 14	14.1			0.123		124.4	96.1	145.6	
17	Caloocan Plaza, near municipal building	29.5		31.1	0.151	24.9	316.6			6.6
18	A. Mabini, North Road, near km 9	24.5		28.1	0.123	28.9	286.2	8.4	6.6	
19	A. Mabini, North Road, near km 7	26.7	8.7	9.8	0.123		308.4	16.8	15.9	
	SAN JUAN DEL MONTE.									
SJ–1	Mariquina Road, between kms 7 and 8	11.4	37.3	48.8	0.123	27.1	114.9		21.9	
2	Corner Blumentritt and Bonifacio	16.3		[a]8.8	0.206	9.9	237.5	10.8	38.1	
3	Market place	12.9	12.9	12.1	0.219	47.7	226.6	tr	11.7	
4	Santa Lucia Barrio	15.7		7.2	0.261	2.1	200	40.8	64.7	
5	Rizal Street, near Burgos	18.1		[a]11.1	0.096	8.5	245.4	14.4	33.1	
6	Ermitaño Barrio, East Street	24.8	3.6	16.3	0.096	23	231.3		14.9	
7	Mariquina Road, Ermitaño Barrio, between kms 8 and 9.	22.9		9.8	0.798	2.1	305.9			
8	Broadway, near First Street, New Manila	17		[a]8	0.055	8.5	295.4		31.1	
9	Cubao Barrio, Mariquina Road, between kms 10 and 11.	14.7		2.8	0.206	4.2	230.3	31.2	68.8	
10	Ortega Street addition	23		10.5	0.123	33.1	282.2			
11	San Pedro Street, near km 6, Mariquina Road	57		5.3	0.098		344.3	18.1	25.9	
	SAN FELIPE NERI.									
SF–1	Hagdaan Bato, Bonifacio Street	20.9		[a]12.5	0.096		219.1	24	41.2	
2	T. Kalazan, near river	14.7		[a]1.5	0.121		149.7	59.4	95.4	
3	Lamayan, corner of Rizal and Vergara	14.3	8.6	9.1	0.098	30.9	275.3		6.6	
4	Blumentritt, between municipal building and school	20.6		tr	0.274		156.8	51	105.1	
5	Mabini Street	26.7	12.1	19.2	0.192	27.1	231.1		9.5	
6	Zanega Barrio	33.7		[a]14.3	3.036	6.4	260.3		21.2	
7	Jolo Barrio	23.2		15.4	0.247	18.9	303.1			

TABLE 2.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities*—Continued.

Tracing No.	Location.	Potassium chloride (KCl).	Sodium chloride (NaCl).	Sodium sulphate (Na_2SO_4).	Sodium nitrate ($NaNO_3$).	Sodium carbonate (Na_2CO_3).	Sodium bicarbonate ($NaHCO_3$).	Magnesium bicarbonate $Mg(HCO_3)_2$.	Calcium bicarbonate $Ca(HCO_3)_2$.	Sodium silicate (Na_2SiO_3).
1	2	2	3	4	5	6	7	8	9	10
	SAN FELIPE NERI—Continued.									
8	Barranca	18.9	----	*6.1	0.151	6.4	238.1	28.8	70.7	----
9	Hagdaan Bato, corner A. Luna and Bonifacio	19.7	28.5	2.7	7.289	----	45.9	90.1	137.6	----
10	Kalentong Street, between kms 9 and 10	20.1	----	4.9	0.055	----	207.1	51.1	89.1	----
11	Jolo Barrio, at J. Coronado	22.9	52.9	42.9	0.151	51	133.5	----	17.4	----
12	Blumentritt Street, in front of market	34.3	100.1	222.1	0.123	23.1	67.8	----	13.1	----
13	Lamayan Barrio, Segura and Rizal Streets	80.1	357.9	29.6	0.091	13.1	171.6	----	40.4	----
	SAN PEDRO MAKATI.									
SP–1	Guadalupe, McKinley Road, between kms 7 and 8	25	----	14.8	0.604	33	170.9	----	----	----
2	McKinley Road, between kms 6 and 7	29.4	----	23.7	0.274	28.3	175.2	----	----	----
3	Guadalupe, Ninety-sixth Street	27	----	22.2	0.370	24.9	225.9	----	8.1	----
4	J. Rizal and P. P. Roxas	13.9	56.8	71	0.124	35.3	74.3	----	----	31.6
5	Olimpia Barrio, J. B. Roxas Street	38.1	31.2	23.7	0.096	15.9	203.2	18.6	23.1	----
6	Bonifacio Street, 1 km east of municipal building	33.6	----	*11.1	0.056	18.9	298.8	----	6.7	----
7	E. Zobel Street	29.5	----	3.7	tr	----	287.8	52.2	64.6	----
8	Cristal Barrio, in front of chapel	51.5	68.5	81.4	0.096	30.1	122.3	----	19.8	----
9	Masilang Barrio, Soliman, near Comercio	13.1	10.3	11.2	0.151	----	249.2	66	98.2	----
10	Tejeron Barrio, McKinley Road, kms 4 and 5	34.3	95.2	59.2	0.096	12.9	244.2	----	3.5	----
11	Culiculi Barrio, near Batangas railroad track	20.1	----	----	0.329	----	273.7	72.1	117.3	----
12	Guadalupe, in front of Dapitan Street	36.5	----	19.2	0.151	----	321.1	25.8	93.3	----
	PASAY.									
P–1	San Roque Barrio, corner Tolentino and Protacio	30.5	14.1	----	0.151	----	160.7	138.1	137.3	tr
2	Malibay Barrio, C. José Street, near chapel	20.1	----	*2.8	0.055	----	270.1	72	124.5	----
3	Santol Barrio, corner Protacio and Decena	47.7	48.4	74.1	0.192	8.5	372.2	19.8	31.2	----

4	Leveriza, near Villaruel	64.8	130.7	23.7	0.123	6.1	407.2	22.8	21.8	
5	Corner Tolentino and Aurora	68.6	251.4	13.9	0.151		252.5	102	109.2	
6	Zamora Street, corner Apelo Cruz, Tabon	82.1	487.1	22.2	0.151		60.3	132.1	226.2	
7	Tambo Barrio, at Camp Claudio	238.2	547.4	170.2	0.055		223.2	39	68.6	

Tracing No.	Location.	Calcium silicate ($CaSiO_3$).	Iron oxide and alumina ($Fe_2O_3+Al_2O_3$).	Silica (SiO_2).	Oxygen to form SiO_3.	Classification.
1	2	11	12	13	14	15
	MANILA.					
M-1	Santiago, near G. Tuason, Sampaloc	4.9	1.2	22.3	1.5	Very mild. Sodic bicarbonated (muriated) alkaline—saline.
2	Plaza Guipit, Sampaloc		1.6	30		Very mild. Sodic bicarbonated alkaline.
3	Plaza Moriones, Tondo		1.6	24		Do.
4	Corner Victoria and Muralla Streets, Intramuros	8.4	3.6	17.1	2.7	Very mild. Sodic sulphated saline.
5	San Lazaro Hospital	2.5	1.6	28.7	0.3	Mild. Sodic sulphated (bicarbonated) alkaline—saline.
6	Esguerra, between Yangco and Franco Streets, Tondo		1.6	34		Mild. Sodic bicarbonated alkaline.
7	Santa Mesa market, at Teresa Street	9.9	1.6	29.7	2.8	Mild. Sodic sulphated (muriated) saline.
8	Estado Street, between Benavides and Magdalena	3.2	2	30.3	6.3	Very mild. Sodic sulphated saline.
9	San Lazaro market, Blumentritt Street	9.9	2	60	1.4	Mild. Sodic bicarbonated alkaline.
10	Santa Clara School, Andalucia Street		1.6	74.1		Mild. Sodic muriated (bicarbonated) alkaline—saline.
11	Antonio Rivera, near Tayuman		1.2	70		Very mild. Sodic muriated (bicarbonated) alkaline—saline.
12	Manrique Street, in front of Sampaloc Church	9.9	1.6	40.9	2.4	Very mild. Sodic bicarbonated (muriated) alkaline—saline.
13	Jesus and Narciso Streets, Pandacan	9.9	2	58.9	1.3	Mild. Sodic muriated (bicarbonated) alkaline—saline.
14	Plaza Miranda, at Quiapo Church		2.4	60		Mild. Sodic muriated (sulphated) saline.
15	O'Donnell, between Lope de Vega and Zurbaran	29	2	46	4	Mild. Sodic muriated saline.
16	Anak Bayan, Paco	11.6	2.4	52.8	4.5	Mild. Sodic bicarbonated alkaline.
17	Del Pan, San Nicolas	12.2	1.6	76.7	1.7	Do.
18	Paco Market, Dart and Herran Streets		2.4	77		Strong. Sodic bicarbonated alkaline.

[a] K_2SO_4.

TABLE 2.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities*—Continued.

Tracing No.	Location.	Calcium silicate ($CaSiO_3$).	Iron oxide and alumina ($Fe_2O_3 + Al_2O_3$).	Silica (SiO_2).	Oxygen to form SiO_3.	Classification.
1	2	11	12	13	14	15
	MANILA—Continned.					
19	Santa Ana Market, Calderon Street		2	57		Strong. Sodic muriated (sulphated) saline.
20	Engineer Island	24.7	1.6	53.2	3.4	Strong. Sodic muriated saline.
21	Plaza de la Virgen, Pandacan		2.4	55		Strong. Sodic sulphated (muriated) saline.
22	Malate Market, Leveriza Street		2.4	68		Strong. Sodic muriated (sulphated) saline.
	CALOOCAN.					
C–1	Novaliches Road, between kms 10 and 11		1.6	23		Very mild. Sodic bicarbonated alkaline.
2	Balon Bato, Novaliches Road, between kms 9 and 10		1.6	26		Do.
3	Cangcong Barrio, Novaliches Road, between kms 8 and 9.	2.6	2	35.7	0.4	Mild. Sodic bicarbonated alkaline.
4	Rizal Avenue extension, between kms 6 and 7		0.8	20		Do.
5	Balintawak, near km 9		2	32		Do.
6	Novaliches Road, between kms 17 and 18		1.6	47		Do.
7	Novaliches Plaza, between kms 17 and 18	1.7	1.2	34.3	2.1	Do.
8	San Bartolome, Novaliches Road, between kms 16 and 17.		4.8	39		Mild. Sodic (calcic) bicarbonated alkaline.
9	Baisa Barrio, Balintawak, between kms 12 and 13		2	54		Mild. Sodic bicarbonated alkaline.
10	Mabini Street, near Sañgandaan	10.7	1.6	65.5	1.5	Do.
11	Dulong Calzada, between kms 8 and 9		1.2	66		Do.
12	Baisa Barrio, Balintawak, between kms 11 and 12		3.6	105		Mild. Sodic (calcic) bicarbonated alkaline.
13	Novaliches Road, between kms 14 and 15		2.8	75		Mild. Calcic (sodic) bicarbonated alkaline.
14	A. Mabini, between kms 8 and 9		1.6	85		Mild. Sodic bicarbonated alkaline.
15	Sampalucan, A. Mabini between kms 7 and 8		1.2	33		Do.
16	Talipapa, Balintawak, between kms 13 and 14		2.4	94		Mild. Calcic (sodic) bicarbonated alkaline.

17	Caloocan Plaza, near municipal building		1.2	42.2	0.8	Mild. Sodic bicarbonated alkaline.
18	A. Mabini, North Road, near km 9	9.6	2	58.1	1.2	Do.
19	A. Mabini, North Road, near km 7	2	1.6	75	0.3	Do.
	SAN JUAN DEL MONTE.					
SJ–1	Mariquina Road, between kms 7 and 8		1.6	31		Very mild. Sodic bicarbonated alkaline.
2	Corner Blumentritt and Bonifacio		2	74		Mild. Sodic bicarbonated alkaline.
3	Market place		1.6	60		Do.
4	Santa Lucia Barrio		1.6	78		Do.
5	Rizal Street, near Burgos		1.6	72		Do.
6	Ermitaño Barrio, East Street		1.6	59		Do.
7	Mariquina Road, Ermitaño Barrio, between kms 8 and 9.	24.9	2.4	49.1	3.4	Do.
8	Broadway, near First Street, New Manila		1.2	59		Do.
9	Cubao Barrio, Mariquina Road, between kms 10 and 11.		2.4	79		Do.
10	Ortega Street addition	6.7	1.2	68.5	0.9	Do.
11	San Pedro Street, near km 6, Mariquina Road		2	86		Do.
	SAN FELIPE NERI.					
SF–1	Hagdaan Bato, Bonifacio Street	2.3	2.4	65.8	0.3	Do.
2	T. Kalazan, near river	9.9	2	72.9	1.4	Very mild. Sodic bicarbonated alkaline.
3	Lamayan, corner of Rizal and Vergara	7.8	1.6	55	1.1	Mild. Sodic bicarbonated alkaline.
4	Blumentritt, between municipal building and school		2.4	86		Mild. Sodic (calcic) bicarbonated alkaline.
5	Mabini Street		1.6	61		Mild. Sodic bicarbonated alkaline.
6	Zanega Barrio		1.6	69		Do.
7	Jolo Barrio	2.5	1.6	59.7	0.3	Do.
8	Barranca		1.2	71		Do.
9	Hagdaan Bato, corner A. Luna and Bonifacio		2	100		Mild. Calcic bicarbonated alkaline.
10	Kalentong Street, between kms 9 and 10		1.6	90		Mild. Sodic bicarbonated alkaline.
11	Jolo Barrio, at J. Coronado		2	75		Very mild. Sodic bicarbonated alkaline.
12	Blumentritt Street, in front of market	6.4	2.4	59.7	0.9	Mild. Sodic sulphated saline.
13	Lamayan Barrio, Segura and Rizal Streets		2	53		Mild. Sodic muriated saline.

TABLE 2.—*Mineral analyses of waters from artesian wells located in Manila and neighboring municipalities*—Continued.

Tracing No.	Location.	Calcium silicate ($CaSiO_3$).	Iron oxide and alumina ($Fe_2O_3 + Al_2O_3$).	Silica (SiO_2).	Oxygen to form SiO_2.	Classification.
1	2	11	12	13	14	15
	SAN PEDRO MAKATI.					
SP–1	Guadalupe, McKinley Road, between kms 7 and 8	14.2	1.6	34.6	1.9	Mild. Sodic bicarbonated alkaline.
2	McKinley Road, between kms 6 and 7	2.5	1.6	35.7	0.3	Do.
3	Guadalupe, Ninety-sixth Street		3.2	54		Do.
4	J. Rizal and P. P. Roxas	16.5	0.8	25.8	6.3	Very mild. Sodic bicarbonated (muriated) alkaline—saline.
5	Olimpia Barrio, J. B. Roxas Street		2.4	42		Mild. Sodic bicarbonated alkaline.
6	Bonifacio Street, 1 km east of municipal building		1.6	52		Do.
7	E. Zobel Street		3.6	75		Do.
8	Cristal Barrio, in front of chapel		1.2	44		Mild. Sodic bicarbonated (sulphated) alkaline—saline.
9	Masilang Barrio, Soliman, near Comercio		2.8	95		Mild. Sodic bicarbonated alkaline.
10	Tejeron Barrio, McKinley Road, kms 4 and 5		1.6	50		Do.
11	Culiculi Barrio, near Batangas railroad track		10.4	98		Do.
12	Guadalupe, in front of Dapitan Street		1.6	85		Do.
	PASAY.					
P–1	San Roque Barrio, corner Tolentino and Protacio		4.8	94		Mild. Sodic (magnesic calcic) bicarbonated alkaline.
2	Malibay Barrio, corner of José Street, near chapel	6.4	3.2	111.7	0.9	Strong. Sodic (calcic) bicarbonated alkaline.
3	Santol Barrio, corner Protacio and Decena		2	87		Mild. Sodic bicarbonated alkaline.
4	Leveriza, near Villaruel		1.6	80		Do.
5	Corner Tolentino and Aurora		9.6	91		Strong. Sodic bicarbonated (muriated) alkaline—saline.
6	Zamora Street, corner Apelo Cruz, Tabon		5.2	89		Mild. Sodic muriated saline.
7	Tambo Barrio, at Camp Claudio		3.2	75		Strong. Sodic (potassic) muriated saline.

[a] K_2SO_4.

[b] $KHCO_3$–29.7, the rest is $NaHCO_3$.

manner: "Two waters which carried the same substance in solution would be classed the same, although the one might contain 200 and the other, 20,000 parts per million of total dissolved matter." In view of this apparent anomaly it was thought advisable to adopt a slightly modified form of classification which will give the reader an idea, not only of the kind but also of the approximate concentration of the predominating constituents.

The following ratings give the same limiting values as adopted by Ellis and Lee,[44] with the difference that in this work they represent the concentration of the predominating constituents, and not the total mineralization of the waters.

The term "very mild" is applied to waters having a concentration of 150 parts per million or less of the predominating constituent or the sum of the predominating constituents; "mild," to waters in which the concentration is between 150 and 500; "strong," between 500 and 2,000; and "very strong," over 2,000.

Haywood-Smith classification.

Class.	Subclass.		
I. Alkaline	Carbonated or bicarbonated.	Sodic.	
		Lithic.	
	Borated.	Potassic.	
	Silicated.	Calcic.	Nongaseous.
II. Alkaline-saline	Sulphated.	Magnesic.	Carbondioxated.
	Muriated.	Ferruginous.	Sulphuretted.
	Nitrated.	Aluminic.	Azotized.
III. Saline	Sulphated.	Arsenic.	Carbureted.
	Muriated.	Bromic.	Oxygenated.
	Nitrated.	Iodic.	
IV. Acid	Sulphated.	Silicious.	
	Muriated.	Boric.	

In the light of the preceding discussion in which it was pointed out that the least-mineralized waters are the best for human consumption, the waters cited in the following tables are arranged according to their mineralization; that is, for each municipality, the order is from the least- to the highest-mineralized well water.

The numbers and depths of the wells were kindly furnished by F. W. McCaw, superintendent of artesian wells, Bureau of Public Works.

On the attached sketch of Manila and vicinity (Plate 1) the locations of the wells have been marked and numbered. The numbers correspond to the tracing numbers in the tables.

[44] United States Geological Survey Water-Supply Paper 446 (1919) 228.

DISCUSSION OF RESULTS

In general, the waters are characterized by the preponderance of sodium salts, a great proportion of which are in the form of sodium bicarbonate, some in the form of sodium chloride, and a few in the form of sodium sulphate. The presence of relatively small quantities of calcium and magnesium salts is also evident, indicating the general soft character of the underground waters within the territory included in this work. The average quantity of total dissolved solids is much lower than 500 parts per million, a quantity that, according to Buswell,[45] imparts to the water a salty or brackish taste, detectible by most people.

Rating these waters by total solids after the method of Ellis and Lee,[46] seventy of the eighty-four samples fall under the rating of moderately mineralized waters and fourteen under the rating of highly mineralized waters. It is interesting to note that all the highly mineralized waters, with the exception of one from San Felipe Neri, were obtained from artesian wells located in Manila and in the municipality of Pasay; and all the artesian waters in Manila having a mineralization above 600 parts per million are located south of Pasig River. Chlorine (as chloride) is the predominating constituent of many of these waters. Both Manila and Pasay are located nearer the sea on a relatively lower level than the neighboring municipalities.

In the course of this survey work, it has been also observed that some waters, which would be classed as highly mineralized, are considered good and palatable by those that use them, and the wells are usually crowded with people drawing water for drinking use at all hours of the day and until late at night. This is especially true of wells M–18 and P–4. In these well waters the sodium and bicarbonic acid radicals are present in relatively much larger quantities than the other constituents, placing them under the group of sodic bicarbonated waters. Two other well waters, marked M–22 and P–7, although of much higher total-solid content, would also be considered, according to Ellis and Lee's method, under the same rating as M–18 and P–4; but unlike these two wells, they are not popular with the

[45] The Chemistry of Water and Sewage Treatment. The Chem. Cat. Co. New York (1928) 71.

[46] U. S. Geol. Surv. Water-Supply Paper 446 (1919) 228.

people living in the neighborhood. Their predominating constituents are sodium and chlorine radicals, placing them under the group of sodic muriated waters. It is evident that, for the majority of the people, highly mineralized sodic bicarbonated waters are more acceptable for drinking purposes than sodic muriated waters of approximately the same mineralization. Well M–22 is also characterized by the presence of abnormal quantities of sodium sulphate, containing the SO_4 radical in the amount of 225 parts per million. This amount is above the minimum medicinal concentration given by Dole [47] in his discussion on the therapeutic action of certain inorganic radicals. This minimum concentration is 150 milligrams per kilogram or 150 parts per million.[48] The waters from wells M–21 and SF–12, containing 250 and 150 SO_4 radical in parts per million, respectively, may be also considered of similar character, with the difference that in this case the SO_4 radical predominates over the Cl radical placing the waters under the group of sodic sulphated waters.

Salty waters, containing sodium chloride below 500 parts per million, according to Dole,[49] will not interfere with normal osmosis. With the exception of well waters M–22 and P–7, M–22 containing 500 parts per million and P–7, 547.4 parts per million, the salt content of the rest of the well waters examined is below the above limit.

About 77 per cent of the wells were found to furnish sodic bicarbonated waters. Dole [50] believes that the smallest concentration of sodium in sodium bicarbonate that would possess therapeutic action is 35 milligrams per kilogram, or 35 parts per million. This quantity computed in the form of sodium bicarbonate ($NaHCO_3$) is equivalent to about 130 parts per million. Of the well waters examined 72.5 per cent contain sodium bicarbonate in amounts larger than this minimum concentration. The well waters containing the highest concentration of sodium bicarbonate are located in Manila; they are from wells M–18, M–16, and M–17; the sodium bicarbonate content of these waters is 584.1, 454.4, and 396.8 parts per million, respectively.

[47] U. S. Geol. Surv. Mineral Resources of the U. S. Washington (1912) 1182.

[48] This concentration given by Dole is based upon the assumption that a person, under usual conditions, drinks 4 kilograms of water per day.

[49] Op. cit. 1184.

[50] Loc. cit.

The calcium and magnesium radicals are present in small quantities only, possibly due to the fact that the wells are located within the region of soft underground waters. In the majority of the wells only traces of magnesium are found. Although very little distinctive action is usually assigned to the calcium radical, the minimum average concentration that would produce therapeutic action is 50 milligrams per kilogram, or 50 parts per million. Only well water P–6, has a little higher concentration of calcium radical than the above minimum limit.

Potassium, according to Cushny, arrests the action of the heart when introduced into the blood,[51] but it has practically no such action when entering the stomach, because it is rapidly excreted in the urine. In view of this opinion, it may be concluded that the potassium salts in the amount they are present in the waters examined have no therapeutic action upon persons that drink these waters.

None of the waters would be strictly classified as hard waters. The highest quantity of total hardness encountered is 230 parts per million (P–29). Although the average limit given by different authors is 200 to 300 parts per million, in the Philippine Islands this limit would be considered fairly rigid.

The average hardness (parts per million) of the waters by municipalities is as follows: In Manila, 15.5; in Caloocan, 42.3; in San Juan del Monte, 49.1; in San Pedro Makati, 37.7; in Pasay, 115.1. These waters, with the exception of those in Pasay, may be considered of similar character, as to degree of hardness to those in North America, located in the following states: All the New England States, the Atlantic States, three southern states (Louisiana, Mississippi, Alabama), and in the Northwest, Washington and Oregon. McDonnell [52] states that the average hardness of the waters in these localities is less than 50 parts per million.

The depths of the wells and the rates of flow have no apparent relation to the total mineralization or the chemical characters of the waters.

[51] Cushny, A. R., Pharmacology and Therapeutics, 5th ed. Lea and Febiger, Philadelphia (1911) 497.

[52] Journ. Am. Wat. Works Ass. No. 2, 22 (1930) 222.

CONCLUSIONS

Sodium and bicarbonic acid radicals are the predominating constituents of the artesian-well waters of Manila and vicinity.

The waters are soft and moderately mineralized. The few highly mineralized waters are located in Manila and Pasay south of Pasig River. Pasay is also characterized with moderately hard underground waters.

Seventy-two and one-half per cent of the waters contain sodium bicarbonate in concentration higher than the minimum that would exercise therapeutic action.

ILLUSTRATION

PLATE 1. Map showing the location of artesian wells in Manila and vicinity.

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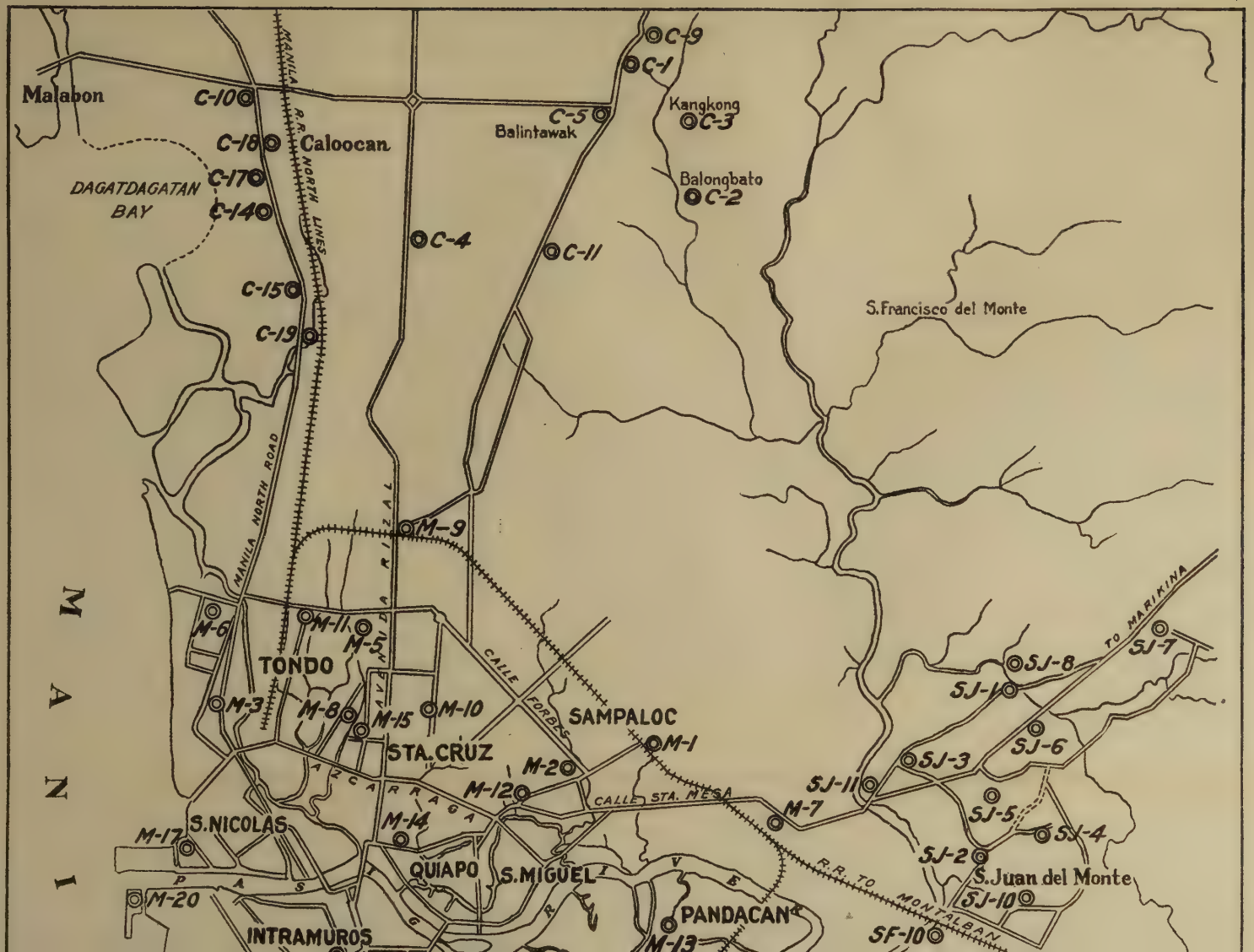
Malabon
C-10
C-18
Caloocan
C-17
C-14
DAGATDAGATAN BAY
MANILA R.R. NORTH LINES
C-15
C-19
C-4
C-5
Balintawak
C-9
C-1
Kangkong
C-3
Balongbato
C-2
C-11
S. Francisco del Monte
MANILA NORTH ROAD
AVENIDA RIZAL
M-9
M-6
M-11
M-5
TONDO
M-3
M-8
M-15
M-10
CALLE FORBES
SAMPALOC
M-1
STA. CRUZ
M-20
M-12
CALLE STA. MESA
M-7
M-17
S. NICOLAS
M-14
QUIAPO
S. MIGUEL
M-20
INTRAMUROS
PANDACAN
M-13
SF-10
MANILA
TO MARIKINA
SJ-8
SJ-7
SJ-1
SJ-6
SJ-3
SJ-11
SJ-5
SJ-4
SJ-2
S. Juan del Monte
SJ-10
R.R. TO MONTALBAN

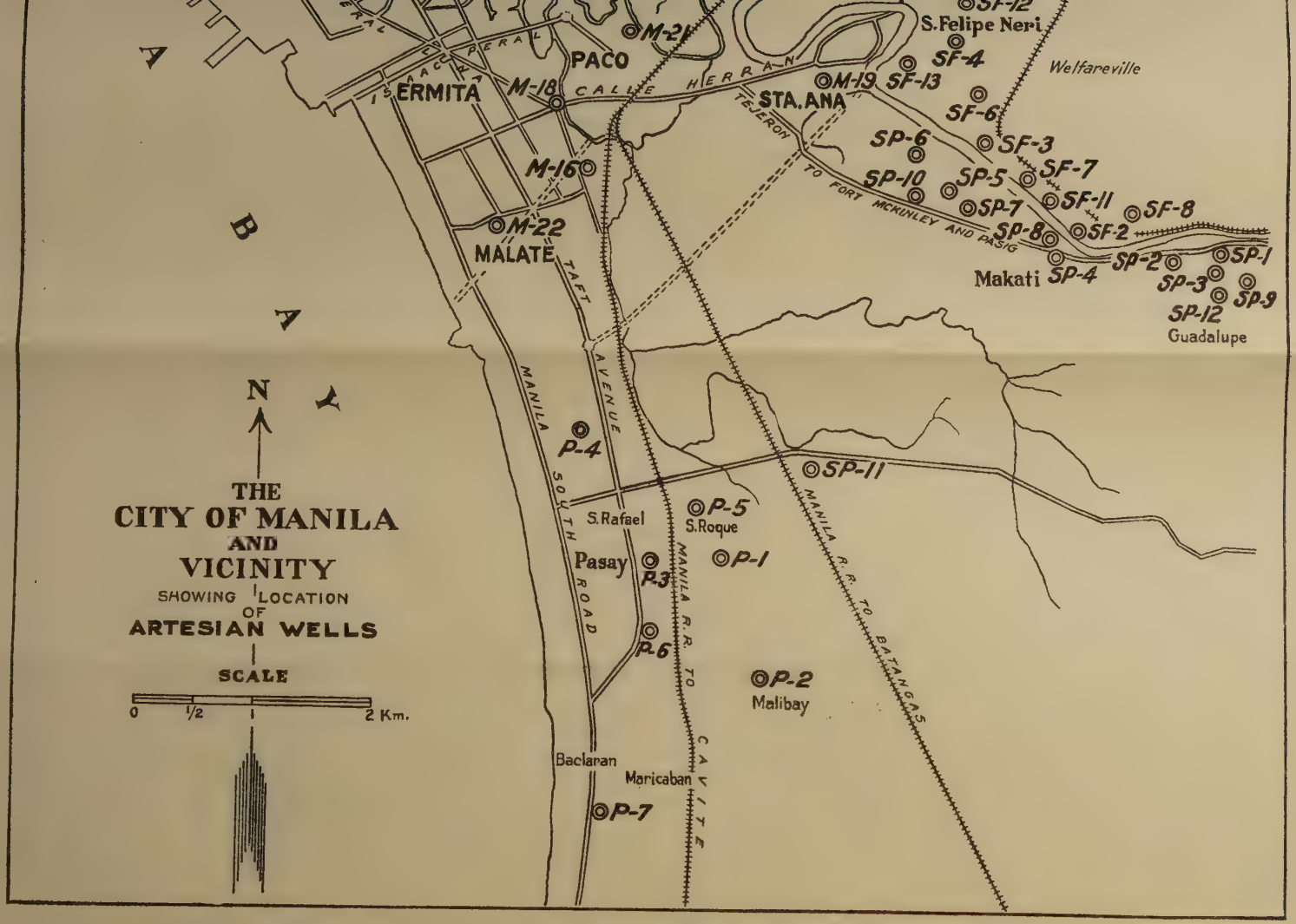

PLATE 1. THE CITY OF MANILA AND VICINITY, SHOWING THE LOCATION OF ARTESIAN WELLS.

RELATIVE RADIOACTIVITY OF DEEP-WELL WATERS IN MANILA AND VICINITY

By R. H. AGUILAR
Of the Bureau of Science, Manila

ONE TEXT FIGURE

Quite recently much interest has been created by radioactive waters. The main cause was the wide propaganda given various imported appliances used to impart radioactive properties to waters placed in contact with them, and the claim that the activated waters possessed curative properties. Taking advantage of this situation, local manufacturers of beverages began to advertise and sell natural radioactive bottled waters, taken from springs and deep wells. By inference, such waters were supposed to possess curative properties. From inquiries made by several persons at the Bureau of Science, it is apparent that this propaganda has created confused ideas in the public mind as to the true nature of radioactivity, resulting in the belief that it is one of the rarest properties of natural waters, and that all radioactive waters are medicinal.

In this connection the following quotations from the work of Collins [1] appear to be of interest.

> Every natural water is more or less radioactive, and therefore the recognition of the presence of a small amount of radioactive material in any spring water does not set that water apart from other natural waters.
>
> Knowledge of the presence of radioactive substances in waters is comparatively recent. Therefore, the radioactivity has been seized as something to talk about and advertise as a remarkable and unique property of many waters which are no more unique in their radioactivity than they are in their wetness.

To correct the wrong idea that has been impressed on the public mind regarding the nature and properties of radioactive waters and to obtain more information on the radioactivity of Philippine natural waters, this study was undertaken. It deals with the relative radioactivity of deep underground waters of the City of Manila and nearby municipalities.

[1] The Radioactivity of Natural Waters, Public Health Reports 41 (1926) 1937.

PREVIOUS WORK ON THE RADIOACTIVITY OF PHILIPPINE WATERS

The first quantitative determination of radioactivity of Philippine waters was made by Wright and Heise in 1916; several springs and some flowing wells were examined.[2] According to the authors, none showed an excessive amount compared with waters from other countries reported in the literature. In 1917, the waters of the mountainous regions of northern Luzon were also studied. A comparison of their radioactivity and that of the waters in the lowlands of Luzon indicated that the typical lowland waters have the higher radioactivity.[3]

COLLECTION OF SAMPLES AND METHODS OF PROCEDURE

All the artesian wells examined, with the exception of two, are pumping wells. The collection of samples from the pumping wells was made after continuous pumping for about twenty minutes. The glass-stoppered collecting bottle was completely filled with the water to prevent loss of activity in transit, through shaking or aëration. The radioactivity measurement was made within an hour after the collection of the sample.

The apparatus used is the "Fontaktoskop" of C. Engler and H. Sieveking.[4] This apparatus, which for some time had been kept unused in the Bureau of Science, was recently readjusted and recalibrated at Braunschweig by Günther and Tegetmeyer.

The calibration tables for the apparatus give the equivalence in volts of the scale divisions on the electroscope. It was certified that the calibration measurements were made by means of a high-tension accumulator battery and referred to a Clark normal element that was tested by the "Physikalisch-Technischen Reichsanstalt." The apparatus is now working satisfactorily. The observed variation in the normal leak was from 10 to 25 volts per hour.

Although the method of procedure is based on the same general principle as the other methods usually followed by most experimenters, however, there are some differences in the details of the various phases of the measurement. The method [5] is herein briefly discussed.

[2] Philip. Journ. Sci. § A 12 (1917) 158.

[3] Philip. Journ. Sci. § A 12 (1917) 293 and 309.

[4] Ztschr. Anorg. Chem. 53 (1907) 1.

[5] Given in the form of a pamphlet, with the calibration tables, by Günther and Tegetmeyer, of Braunschweig.

Measuring apparatus.—The Fontaktoskop consists of the following principal parts:

(*a*) Electroscope with base after Elster and Geitel modified in such a way that the leaflets are suspended.[6] It is provided with microscope and scale.

(*b*) A tin container of 10 liters capacity, provided near the bottom with glass stopcock outlet.

(*c*) A dispersion cylinder with connecting shaft.

Measurement.—The actual measurement of radioactivity in waters may be divided into two main periods:

1. Driving off the emanation from the water, by shaking it with air in the tin container.

2. Determination of the electrical conductivity of the air in the vessel.

Order of procedure.—(*a*) Charge the electroscope; determine the normal leak, by reading on the scale the rate of downward fall in the tension of the leaflets, using a stop watch. The normal leak is caused by the presence of room air in the tin container.

(*b*) Remove the electroscope, pour in the water to be tested carefully and very slowly, letting it run on the inside walls of the container.

(*c*) Cover the mouth of the container with a tight fitting rubber stopper, and shake the water energetically for one-half minute.

(*d*) Place the container on a level surface, and allow sufficient time for the water to drain down from its sides.

(*e*) Open the stopcock outlet to release the excess pressure.

(*f*) Remove the rubber stopper, put the electroscope in its place, charge and note the rate of downward fall in the tension of the leaflets, in the same manner as in the determination of the normal leak.

Computation.—(*a*) The scale readings are now reduced to volts by means of the calibration tables, and recomputed on the basis of an hour and 1 liter.[7]

[6] Zeitsch. für Elektrochemie 11 (1905) 715 and Zeitsch. für Anorg. Chemie 53 (1907) 5.

[7] Sometimes, when the sample of water is highly radioactive, a smaller quantity is taken and shorter periods of measurement are adopted. Throughout this work, however, the quantity used was 1 liter and six readings were taken at 5-minute intervals.

(*b*) The normal leak recomputed on the basis of one hour is to be subtracted from these results.

(*c*) The found voltage is calculated in Mache units by means of the formula, $A = \frac{V}{300} \cdot \frac{C}{3,600} \cdot 1,000$,[8] in which V = fall of potential in volts per hour, and C = capacity of the apparatus.

One Mache unit is considered in this work to be equivalent to $\frac{1}{2,670}$ microcurie, or in other words, one curie of emanation per liter, equals a concentration of 2,670 million Mache units.[9]

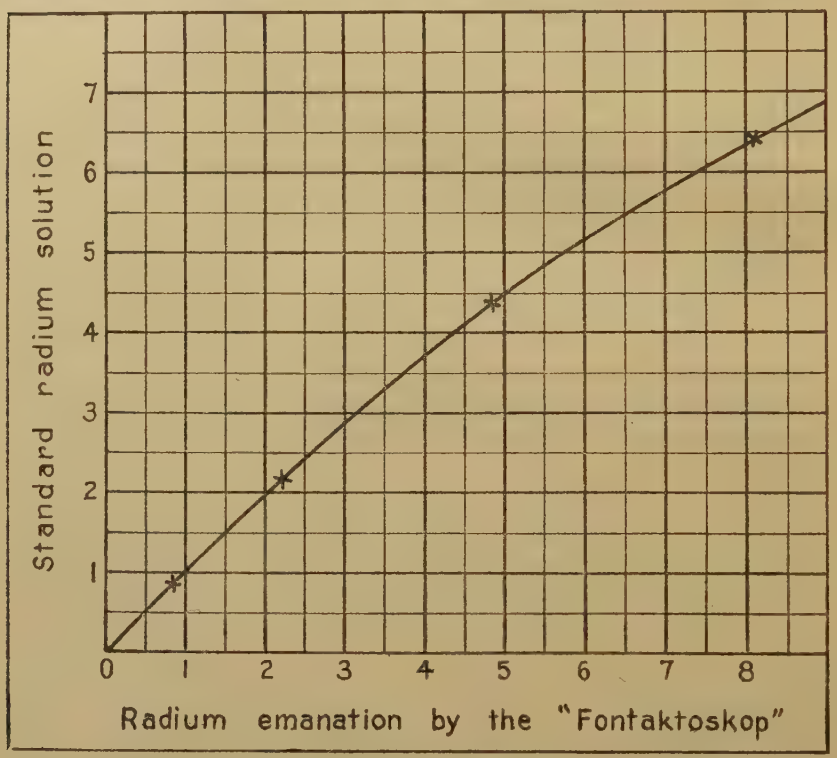

FIG. 1. Correction curve for the Fontaktoskop. Marginal figures are in Mache units.

In order to find how the results of tests would compare with solutions, prepared from a standard, containing known quantities of radium emanation, these solutions were tested by using the apparatus in the same manner as it had been used in testing water samples for radioactivity. The results show that for lower contents of radium emanation there is practically no dif-

[8] Engler, C., H. Sieveking, and A. Koenig, Chem. Zeitg. 38 (1914) 425.
[9] Sc. Am. Suppl. 2025 (1914) 260.

ference between the emanations found by measurement and the value of the standards, but for higher concentration, the results appear to differ from the standards in the manner shown by the curve in fig. 1. Accordingly this curve has been used to correct the results of the test.

RETESTS OF THE WATERS FROM SIBUL SPRINGS AND FROM A FLOWING WELL AT PARAÑAQUE

The waters of Sibul Springs, Bulacan, and of the flowing well at Parañaque, Rizal, which were considered by Heise [10] to possess fairly constant radium-emanation content, have been retested by using the Fontaktoskop. The object was, primarily, to compare the results obtained by this method with those obtained by Wright and Heise [11] in 1916; and, secondarily, to get additional data on the constancy of the radioactivity of these spring and well waters. The agreement between the results of two determinations is very satisfactory, as shown in Table 1.

TABLE 1.—*Comparative results of two different radioactivity measurements made in 1916 and in 1929.*

Locality.	Radium emanation per liter. Grams × 10–12.	
	1916	1929
Flowing well, Parañaque, Rizal	632 (1.68 maches)	663 (1.77 maches).
Sibul Springs, San Miguel de Mayumo, Bulacan	1,284 (3.45 maches)	1.232 (3.29 maches).

The measurement of the water of the Parañaque well was made in situ, but that of the Sibul Springs water was made in Manila twenty-five hours after the water sample had been collected. The initial radium emanation was obtained by computation from the formula $I_0 = Ie^{at}$, using 0.00724 for the value of a; t is the elapsed time in hours;[12] e, the base of the Napierian system of logarithm.

ORIGIN AND NATURE OF RADIOACTIVITY IN NATURAL WATERS

Boltwood,[13] in a series of experiments, demonstrated that water can very readily acquire radioactive properties through brief contact with uranium minerals or with gaseous mixtures containing radium emanation. In the light of these experiments he explains the occurrence of radioactivity in natural waters as

[10] Philip. Journ. Sci. § A 12 (1917) 310.
[11] Philip. Journ. Sci. § A 12 (1917) 145.
[12] Boltwood, B. B., Am. Journ. Sci. IV 18 (1904) 383.
[13] Op. cit. 385–387.

due to extremely minute traces of uranium in the rocks and soils through which these waters percolate in their underground passage.

From the above observation and from our knowledge of the properties of radioactive substances, it is apparent that underground waters acquire their radioactivity either by absorbing the radioactive gases, which are constantly thrown off by minute quantities of radioactive minerals distributed in the bosom of the earth, or by decomposing and dissolving small quantities of these minerals.

The activity due to dissolved gases is necessarily of a temporary nature, because as soon as the water is removed from its source, its activity begins to diminish, falling to one-half of its original value [14] in about 3.9 days. The activity due to dissolved radioactive minerals is of a permanent nature, because the supply of emanation is being constantly renewed by the decomposition of the active minerals.

Studies made by various authors indicate that the radium emanation encountered in a great proportion of natural waters is practically all due to radioactive gases that have diffused into them, rather than to radium salts in solution. Such have been the experiences of Schmidt and Moore,[15] in studying the radioactivity of the thermal waters of Yellowstone National Park; of Wright and Heise,[16] in their study of the radioactivity of Philippine waters; of Satterly and Elworthy,[17] in their investigations of the mineral springs of Canada; and of T. F. Buehrer, in his study of the radioactivity of the thermal waters of Castle Hot Springs, Arizona.[18]

One of the most radioactive waters known in the world is the Quelle am Schweitzergang at Joachimsthal, Bohemia.[19] The radium emanation content of the water is approximately 70,000 units per liter (187 Mache units per liter). In the neighborhood of the spring, the pitchblende that has been the chief European source of radium is mined. More highly radioactive than this, however, is one of the hot-spring waters in Arkansas. According to Deaderich, an investigation made by Professor Boltwood, of Yale University, in 1904 showed this spring water to contain

[14] Boltwood, B. B., Am. Journ. Sci. IV 20 (1905) 128–132.
[15] U. S. Geol. Surv. Bull. 395 (1909) 30.
[16] Philip. Journ. Sci. § A 12 (1917) 158.
[17] Canadian Dept. of Mines, Mines Branch, Bull. 16 (1917) 6.
[18] Am. Journ. Sci. 213 (1927) 447–448.
[19] Canadian Dept. of Mines Bull. 16 (1917) 47.

an activity of 265.6 Mache units.[20] In the Philippine Islands, the most highly radioactive water encountered by Wright and Heise is the water from artesian well 686 of the Municipality of Batangas, Batangas. Its emanation content is equivalent to $2{,}100 \times 10^{-12}$ grams of radium per liter [21] (5.6 Mache units per liter).

A more highly radioactive water than this, however, is the water from SP–1, located in San Pedro Makati, Rizal. Its radium emanation content is equivalent to 5.94 maches ($2{,}225 \times 10^{-12}$).

Few waters containing relatively higher quantities of radium salts in solution have been reported. Among those showing the highest activity due to dissolved radioactive minerals are: (*a*) The waters from Kings Well at Bath, England, containing 0.1387 milligram radium per million liters [22] (0.37 Mache unit per liter); (*b*) the waters from Hawthorne 2, Saratoga Springs, New York, containing 99×10^{-12} grams of radium per liter [23] (0.264 Mache unit per liter); and (*c*) the waters from Fairmount Springs, British Columbia, containing 0.1 millionth of a milligram of radium per liter [24] (0.267 Mache unit per liter). In the Philippine Islands, none of the springs or deep wells examined in previous work or in this work has been found to contain more than traces of radioactivity due to radioactive minerals in solution.

THERAPEUTIC PROPERTIES OF RADIOACTIVE WATERS

Since the appearance on the local market of "radium ore jars," the inner walls of which are lined with radioactive minerals, for the purpose of imparting larger quantities of radioactivity to waters placed within, all kinds of literature and advertisements on radioactivity have been published and liberally distributed in the city and in the provinces. It was naturally to be expected that these publications would contain only opinions in favor of the use of radioactive waters in the treatment of human illness, but such a one-sided way of presenting the subject may lead to wrong interpretations on the part of the public, in regard to the usefulness and true health value of radioactive waters.

[20] New York Med. Journ. 103 (1916) 550.
[21] Philip. Journ. Sci. § A 12 (1917) 163.
[22] Sir William Ramsay, Chem. News 105 (1912) 134.
[23] Moore and Whittemore, Journ. Ind. Eng. Chem. 6 (1914) 552.
[24] Boyle and McIntosch, Trans. Roy. Soc. Canada § III 7 (1913) 163.

The present status of the therapeutic value of radioactive waters, judging from the works of various authors, appears to be quite indefinite; that is, it is still under study and observation. Burham,[25] in his studies on the value of radioactive waters in the treatment of gout, came to the conclusion that the action is in many cases, if not in every case, a favorable one. Lautman, [26] writing of the physiological action of the natural radioactive waters of Hot Springs, Arkansas, stated that these waters may be considered to produce a beneficial effect in the treatment of rheumatism, gout, chronic arthritis, neuralgia, nephritis, chronic skin diseases, etc., but are of no value in any form of tuberculosis and malignant neoplasms. He added, however, in his concluding remarks, that there are always skeptical persons who would maintain that the change and the rest account for the remarkable improvements and cures that are clinically observed at hot springs. Field,[27] in January, 1926, wrote an article on radium therapy, and in his reference to the use of radioactive waters for certain types of faulty elimination, he says that 90 per cent of the reported cases were favorable, and yet the amount of energy supplied by such waters was comparatively small. One year later another article on the same subject appeared.[28] According to this article, the "sipping cure" method, or application of radium emanation by inhalation or by drinking activated waters, has not been effective and it has consequently dropped into disuse; in its place, the intravenous administration of soluble salts of radium has been adopted. Even with this method, the results have been meager, transient or entirely negative; hence the following concluding statement: "Radium treatment is rarely now employed in our wards in spite of the fact that it always can be had on request."

RESULTS

The radium-emanation content of the different well waters examined is shown in Table 2. The depths of the wells, capacity, temperatures, and total mineralization of the waters are also included in the table to facilitate the study of any relation that may exist between these properties and their radioactivity.

[25] Med. Rec. 81 (1912) 117–119.

[26] Southwestern Med. 8 (1924) 435–437.

[27] Am. Med. 32 (1926) 40.

[28] Allen, E. V., H. H. Bowing, and L. G. Rowntree, Journ. Am. Med. Assoc. 88 (January, 1927) 164.

For every municipality the data are arranged in ascending order in relation to the total mineral content of the waters.

GENERAL CONSIDERATION OF THE RESULTS

No abnormal quantities of radioactivity have been encountered in the artesian-well waters examined. The radium emanation of 5.62 maches, the highest reported by Wright and Heise in 1916,[29] and 5.94 maches, the highest encountered in this work, are too low compared with the dose considered to be medicinal.

Compared with the waters of the famous springs of Europe and America, the quantities found would also appear very little. The Quelle Am. Schweitzergang, at Joachimsthal, Austria, has 186.8 maches (70,000 units). The Choussy Spring, La Bourboule, France, has 61.2 maches (22,900 units). The Lambinet Spring, Plombieres, has 42.4 maches (15,900 units); and the Imperial Spring, Hot Springs, Arkansas, has 26.9 maches (10,000 units).[30]

The Sibul Springs water, widely known in the Philippine Islands as medicinal water, according to the results of tests possesses about as much radioactivity as the waters from the following wells: In Manila, the wells located at Santiago Street, near G. Tuason, at Plaza Guipit, and at Plaza Miranda, near the Quiapo Church; in Caloocan, the wells located at the municipal plaza and at A. Mabini Street, near kilometer 7; and in San Pedro Makati, the well located at the corner of José Rizal and P. P. Roxas Streets.

RELATION BETWEEN RADIOACTIVITY AND OTHER PROPERTIES

The quantity of emanation seems to bear no general relation to the commonest physical and chemical properties of the waters. Differences in depths, rates of flow, temperatures, and total mineralization of the water, as a whole, appear to be independent of the differences in radioactivity. Schlundt and Moore[31] have pointed out that no detectible difference in activity exists between acid and alkaline waters, Wright and Heise[32] found no general relations between the chemical quality of a water and its radioactivity, and Satterly and Elworthy[33] believe that fresh-

[29] Philip. Journ. Sci. § A 12 (1917) 145.
[30] Canadian Dept. of Mines Bull. 16 (1917) 46.
[31] U. S. Geol. Surv. Bull. 395 (1909) 30.
[32] Philip. Journ. Sci. § A 12 (1917) 159.
[33] Canadian Dept. of Mines Bull. 16 (1917) 48.

TABLE 2.—*Radioactivity of artesian-well waters of Manila and vicinity.*

Tracing No.	Location.	Depth of well.	Date of collection of sample.	Capacity of well; liters per minute.	Temperature, °C.		Total mineralization, in parts per million.	Radium emanation, in Mache units per liter.
					Water.	Air.		
	MANILA.	*Meters.*	1929					
M-1	Santiago, near G. Tuason, Sampaloc	160	July 23	29	30.4	27.5	215	3.01
2	Plaza Guipit, Sampaloc		Sept. 11	31	30.5	29.4	250	3.89
3	Plaza Moriones, Tondo	260	May 29	30	33	29.4	260	2.05
4	Corner Muralla and Victoria Streets, Intramuros	223	May 20	30	31.5	30.9	275	1.64
5	San Lazaro Hospital	269	July 13		30.5	29.5	295	2.06
6	Esguerra, between Yangco and Franco Streets, Tondo	119	July 22	35	30.1	30.1	305	1.95
7	Santa Mesa Market, at Teresa Street	170	July 11	24	30.6	29.8	315	2.14
8	Estado, between Benavidez and Magdalena		June 8	8	31.5	29.7	350	0.58
9	San Lazaro market, at Blumentritt Street	129	June 27	33	29.5	29.2	350	1.86
10	Santa Clara School, Andalucia Street	136	July 18	27	29.5	28.4	370	1.32
11	Antonio Rivera, near Tayuman	122	July 20	34	30.1	29.4	370	1.10
12	Manrique, in front of Sampaloc Church	136	June 11	26	29.5	33	375	2.08
13	Jesus and Narciso, Pandacan	144	June 25	34	30.2	32.1	395	0.76
14	Plaza Miranda, near Quiapo Church	153	June 4	34	30.2	28.6	485	3.75
15	O'Donnell, between Lope de Vega and Zurbaran	118	July 6	29	29.6	27.5	545	1.80
16	Anak Bayan, Paco	154	July 9	33	30.5	25.6	545	2.40
17	Del Pan, San Nicolas	92	July 19	45	30.2	29.1	595	1.77
18	Paco Market, Dart and Herran Streets	101	June 21	36	29.5	30.7	625	1.87
19	Santa Ana Market, Calderon Street	166	June 11	28	30.2	29.6	755	1.93
20	Engineer Island	178	Oct. 8				880	0.91
21	Plaza de la Virgen, Pandacan	205	Aug. 12	30	29.3	28.4	965	2.40
22	Malate Market, at Leveriza	198	May 17	34	31.1	32.4	1,145	1.32

	CALOOCAN							
C-1	Novaliches Road, between kms 10 and 11	-------	Sept. 19	30	28.5	27.9	180	1.67
2	Balon Bato, Novaliches Road, between kms 9 and 10	150	Sept. 24	32	29.2	28.3	180	2.22
3	Cangcong Barrio, Novaliches Road, between kms 8 and 9	107	Sept. 27	63	28.6	28.5	215	0.80
4	Rizal Avenue extension, between kms 6 and 7	151	July 3	30	29.8	29.6	220	1.38
5	Balintawak, near km 9	126	Oct. 1	39	29.6	28.8	225	2.21
6	Novaliches Road, between kms 17 and 18	107	June 18	34	28.6	35.0	235	1.77
7	Novaliches Plaza, between kms 17 and 18	102	Aug. 3	28	28.3	25.4	235	1.38
8	San Bartolome, Novaliches Road, between kms 16 and 17	100	Aug. 8	26	27.7	26.1	270	1.60
9	Baisa Barrio, Balintawak, between kms 12 and 13	107	Aug. 29	31	28.1	23.6	270	2.28
10	Mabini, near Sañgandaan	123	June 6	34	29.7	31.9	275	0.95
11	Dulong Calzada, between kms 8 and 9	145	July 25	27	29.7	26	275	1.67
12	Baisa Barrio, Balintawak, between kms 11 and 12	-------	Sept. 5	18	28.9	30.3	280	1.86
13	Novaliches Road, between kms 14 and 15	84	Aug. 20	25	28.0	26.5	300	1.12
14	A. Mabini, between kms 8 and 9	124	Aug. 27	29	29.2	29.5	310	1.49
15	Sampalucan, Mabini, between kms 7 and 8	191	July 16	30	31	28.4	320	0.58
16	Talipapa, Balintawak, between kms 13 and 14	116	Aug. 24	27	29.2	26.1	330	0.68
17	Caloocan Plaza, at municipal building	218	Sept. 17	50	30.4	27.5	330	3.06
18	A. Mabini, North Road, near km 9	205	Sept. 28	13	31.2	29	330	1.56
19	A. Mabini, North Road, near km 7	84	Oct. 3	37	28.5	25.2	335	3.75
	SAN JUAN DEL MONTE.							
SJ-1	Mariquina Road, between kms 7 and 8	157	Sept. 20	29	30.1	31.2	245	2.30
2	Corner Blumentritt and Bonifacio	-------	Aug. 28	8	29.5	29.5	290	1.45
3	Market place	101	May 23	21	29.5	31.1	295	0.40
4	Santa Lucia Barrio	72	July 31	27	29.7	29.5	295	2.69
5	Rizal Street, near Burgos	-------	Sept. 9	30	30.2	29.3	295	1.10
6	Ermitaño Barrio, East Street	55	Oct. 4	49	30	29.4	295	1.66
7	Mariquina Road, Ermitaño, between kms 8 and 9	-------	July 2	34	29	30.4	300	1.32
8	Broadway, near First Street, New Manila	-------	Sept. 23	14	29.5	32.3	300	1.77
9	Cubao Barrio, Mariquina Road, between kms 10 and 11	150	Sept. 13	31	28.5	29.0	305	1.77
10	Ortega Street, San Juan Heights addition	93	Aug. 2	36	30	28	320	1.32
11	San Pedro, Mariquina Road, near km 6	93	Oct. 2	33	28.4	29.9	390	2.80

TABLE 2.—*Radioactivity of artesian-well waters of Manila and vicinity.*—Continued.

Tracing No.	Location.	Depth of well.	Date of collection of sample.	Capacity of well; liters per minute.	Temperature, ° C.		Total mineralization, in parts per millions.	Radium emanation, in Mache units per liter.
					Water.	Air.		
	SAN FELIPE NERI.	*Meters.*	1929					
SF–1	Hagdaan Bato, Bonifacio Street	120	Oct. 8	34	29.7	25.2	275	0.91
2	T. Kalazan, near river	47	Sept. 26	38	28.7	28.9	295	2.23
3	Lamayan, corner Rizal and Vergara	110	Oct. 1	35	29.6	29.6	300	0.84
4	Blumentritt, between municipal building and school	63	Aug. 1	23	28.7	27.5	305	1.98
5	Mabini Street	126	Sept. 10	28	29.8	29.6	305	2.74
6	Zanega Barrio	96	Aug. 6	38	29.1	26.8	310	0.85
7	Jolo Barrio	90	Aug. 19	26	29.2	28.1	310	2.30
8	Barranca	109	Sept. 14	30	28.6	30.5	315	1.06
9	Hagdaan Bato, corner A. Luna and Bonifacio	60	Aug. 21	27	29.0	29.0	325	0.98
10	Kalentong Street, between kms 9 and 10	46	Sept. 7	31	28.6	26.7	335	1.40
11	Jolo Barrio, at J. Coronado	106	Aug. 23	33	29.5	29.6	345	1.88
12	Blumentritt, in front of market	270	July 30	24	30.8	29.1	495	2.38
13	Lamayan Barrio, Segura and Rizal Streets	130	Sept. 25	33	29.6	30.5	685	2.14
	SAN PEDRO MAKATI.							
SP–1	Guadalupe, McKinley Road, between kms 7 and 8	129	Aug. 7	34	29.5	27.2	225	5.94
2	McKinley Road, between kms 6 and 7	108	July 27	33	29.9	28	230	2.51
3	Guadalupe, Ninety-sixth Street	84	Aug. 22	18	30	30.2	280	2.61
4	Jose Rizal and P. P. Roxas	171	June 29	31	30.1	30.2	285	3.12
5	Olimpia Barrio, J. B. Roxas	129	Sept. 26	17	30.2	32.6	300	2.09
6	Bonifacio Street, 1 km east of municipal building	104	Oct. 3	36	28.8	25.2	305	2.12
7	E. Zobel Street	124	Oct. 7	30	28.9	28.5	360	0.54
8	Cristal Barrio, in front of chapel	220	Oct. 5	36	31.3	29.1	365	2.79

9	Masilung Barrio, Soliman, near Comercio	128	Oct. 24	28	31.3	29.1	390	1.02		
10	Tejeron Barrio, McKinley Road, between kms 4 and 5	109	Sept. 18	32	29.5	33	410	2.20		
11	Culiculi Barrio, near Batangas railroad	55	Aug. 10	33	29	27.1	415	1.33		
12	Guadalupe, in front of Dapitan Street	130	Sept. 6	22	30.3	28.2	420	1.66		
	PASAY.									
P-1	San Roque Barrio, corner Tolentino and Protacio	69	Aug. 30	31	28.4	26.8	415	4.63		
2	Malibay Barrio, San Jose Street, near chapel	149	Aug. 26	29	30.2	30.5	425	1.79		
3	Santol Barrio, corner Protacio and Decena	179	Sept. 12	29	32.2	31.5	535	1.42		
4	Leveriza, near Villaruel		July 29	29	31.0	29.3	585	2.37		
5	Corner Tolentino and Aurora	108	Aug. 5	35	29.5	26.4	730	1.78		
6	Corner Zamora and Apelo Cruz, Tabon Barrio	92	July 26	33	28.7	25.4	935	1.97		
7	Tambo Barrio, at Camp Claudio		May 18	37	30.7	31.5	1,245	1.44		

water springs are nearly always more temporarily radioactive than mineralized waters. Although none of the waters examined may be considered as highly mineralized as the spring water reported by Satterly and Elworthy, nevertheless, it has been observed that in the municipalities of San Pedro Makati and Pasay, the waters having a lower content of total mineral matter are relatively more radioactive than the more-mineralized waters. This generalization, however, is not applicable to the rest of the well waters.

THERAPEUTIC VALUE

According to Collins,[34] the radioactivity should be between 20 and 500 millimicrocuries per liter (53.4 to 1,334 maches) in order to be considered at all as a factor in the use of water as medicine. On the basis of this statement it is evident that none of the waters examined may be considered medicinal because of radium emanation content.

The general results, however, show that the quantity of radioactivity compares very favorably with that found in a large proportion of natural waters in other parts of the world. A resumé of radioactive measurements made by different authors appears in the same article of Collins, as follows; 72 per cent of 422 spring waters in Germany gave radioactivity of less than 2.5 millimicrocuries (6.67 maches) per liter, 14 waters at Saratoga Springs, New York, were measured and found to contain 0.039 to 0.88 millimicrocurie per liter (0.1 to 2.34 maches), 23 well waters and 47 spring waters in Canada gave 0.0014 to 0.176 millimicrocurie (0.003 to 0.47 mache) and 0.0112 to 0.64 millimicrocurie (0.03 to 1.70 maches), respectively. Eighty-five per cent of 178 mineral waters in Colorado gave less than 2.5 millimicrocuries (6.67 maches). In this work the minimum radioactivity encountered is equivalent to 0.40 mache (SJ–3) and the maximum is 5.94 maches (SP–1). Although none of the waters gave a higher radioactivity than 5.94 maches, it is safe to assume that many of these waters possess as much radioactivity as some of the waters from the well-known Saratoga and Colorado springs.

[34] U. S. Pub. Health Reports 41, No. 37 (1926) 1937.

CONCLUSIONS

There is no wide variation in the radioactivity of the waters examined.

Although no abnormal quantities of radium emanation have been encountered, the general results compare very favorably with the average results obtained in other parts of the world.

As has been found true of a large proportion of natural waters elsewhere, the radium-emanation content of these waters is far below the minimum quantity that those who have studied the subject consider necessary to produce any therapeutic effect.

ILLUSTRATION

TEXT FIG. 1. Correction curve for the Fontaktoskop. Marginal figures are in Mache units.

BACTERIOLOGICAL SURVEY OF ARTESIAN WELLS IN MANILA AND VICINITY

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The regulation of the Philippine Health Service requires that all newly constructed artesian wells must be examined bacteriologically and the findings must conform with the requirements of the standard for drinking waters before the wells are opened to the public. The artesian wells that are in use by the public are examined bacteriologically from time to time at the discretion and request of the Philippine Health Service. The standard for untreated drinking waters in the Philippines is that the water must not contain more than 500 colonies per 1 cubic centimeter and the test for *Bacillus coli* must be negative. The standard for treated waters is that the water must not contain more than 100 colonies per 1 cubic centimeter and the *B. coli* test must be negative.

In connection with a survey made for the purpose of ascertaining the chemical quality of the artesian well waters, a bacteriological survey of these wells was made simultaneously. Only one bacteriological examination of each well was performed. The examination, however, was performed at random; therefore, it gives an account of the conditions prevailing in these artesian wells at that time.

The bacteriologic examination of the artesian wells concerned was carried out in two directions. 1. The total number of colonies per 1 cubic centimeter of the water was ascertained. 2. Search was made for fæcal contamination. This was done in two ways. Search was made for presence of *B. coli* and for choleralike vibrios.

COLLECTING OF SAMPLES

The samples were collected by the bacteriologist of the Bureau of Science, in person, in such a way that the water was pumped for about ten minutes before the sample was taken. The samples were collected in wide-mouthed, cotton-stoppered, sterilized, 200

cubic-centimeter bottles. The examination was performed immediately upon arrival at the laboratory.

COLONY COUNT

For this purpose agar plates were used. By means of sterilized graduated pipettes, 0.1 and 0.5 cubic centimeter of water was placed at the bottom of a sterile Petri dish. Melted agar that had been kept at 40° C. was poured into the Petri dish and thoroughly mixed with the water by inclining the dish. Incubation at 37° C. for forty-eight hours followed. Colonies were counted at the end of forty-eight hours incubation and an average number of colonies per 1 cubic centimeter was calculated.

TEST FOR B. COLI

By means of sterile pipettes, 1 cubic centimeter and 10 cubic centimeters, respectively, of each particular sample of water was placed in Smith fermentation tubes containing lactose bouillon. The Smith tubes were incubated for forty-eight hours and if they showed gas production, further search for *B. coli* was made. This part of the procedure just mentioned is referred to in the table as presumptive test for *B. coli*. The verification of presence of *B. coli* in the fermentation tubes that showed gas production was carried out by planting several loopfuls of the bouillon on the surface of an eosin-methylene blue-lactose agar plate. After twenty-four hours incubation, the colonies were examined. Colonies showing dark discolorization and metallic luster were transplanted for further identification.

TEST FOR VIBRIOS

After the necessary amounts were taken for the colony count and *B. coli* test the remainder of each sample of water was enriched by adding an equal amount of cholera peptone. After twenty hours incubation several loopfuls of the water peptone mixture were planted on the surface of Dieudonne-alkaline blood agar-plates. The colonies that developed during twenty-four hours incubation of the plates were examined to determine whether or not they consisted of vibrios. Hanging drop, smears stained with diluted fuchsin, and serum agglutination tests were made.

DISCUSSION

From Table 1 it is evident that of seventy-two artesian wells examined only three were found to contain more colonies per 1 cubic centimeter than is permitted by the standard. Two of

these three artesian wells contained more than 900 colonies per 1 cubic centimeter, and one exceeded slightly the number of colonies allowed by the standard. All the rest of them came within the standard requirements with regard to the number of colonies per 1 cubic centimeter. Samples from eight wells exceeded 100 colonies per 1 cubic centimeter but had less than 200 colonies per 1 cubic centimeter, while the rest showed less than 100 colonies per 1 cubic centimeter.

With regard to the presumptive test for *B. coli*, five wells gave positive gas formation in amounts of 10 cubic centimeters of the water, while ten wells gave positive gas production in 1 cubic centimeter and 10 cubic-centimeter amounts.

Confirmatory test for *B. coli* was negative in all samples of water.

The test for choleralike vibrios showed that seven of the wells were positive at the time of the test.

THE SIGNIFICANCE OF FINDINGS

The colony count is usually taken as an indication of the number of bacteria per cubic centimeter of the tested water. This manner of estimation is only approximate since one colony does not necessarily originate from one bacterium. It may happen that a clump of bacteria will give rise to one colony. However, the number of colonies encountered on plates is a fair indication of the bacterial content of the water. In this respect, the fact must be kept in mind that the bacterial content will increase rapidly on storage under ordinary room temperature. The factors responsible for the rate of multiplication of bacteria upon storage are the initial number of bacteria in the water; the amount of suspended or dissolved mineral, but particularly organic substances; and the temperature. In the Tropics the temperature naturally is more favorable throughout the year for the multiplication of bacteria in water than it is in cold countries. The examination concerning colony counts should be made, therefore, as soon as possible after the sample of water has been taken. If the initial bacterial count of a given water is very low, the examination may still give satisfactory results when performed two hours after taking the sample. The multiplication of bacteria in the water goes on by geometric progression, and the curve which is plotted out of the colony count performed at intervals of time naturally rises rapidly at room temperature after twelve hours storage. Treated waters show considerable inhibition of bacterial multiplication

TABLE 1.—*Results of bacteriologic examinations of artesian water from wells in Manila and vicinity.*

Tracing No.	Location.	Well No.	Date of collection of samples.	Number of colonies per cc.	Presumptive test.		*B. coli.*	Choleralike vibrios.
					1 cc.	10 cc.		
	MANILA.		1929					
M–1	Santiago, near G. Tuason, Sampaloc	1921	July 23	5	—	—	—	Negative.
2	Plaza Guipit, Sampaloc	-------	Sept. 11	167	+	+	—	Do.
3	Plaza Moriones, Tondo	-------	May 29	10	—	—	—	Do.
4	Corner Muralla and Victoria Streets, Intramuros	1939	May 20	10	—	—	—	
5	San Lazaro Hospital	1528	July 13	4	—	—	—	
6	Esguerra, between Yangco and Franco Streets, Tondo	1929	July 22	56	—	—	—	Negative.
7	Santa Mesa Market, at Teresa Street	1505	July 11	7	—	—	—	Do.
8	Estado Street, between Benavidez and Magdalena	1456	June 8	15	—	+	—	Do.
9	San Lazaro market, at Blumentritt Street	1479	June 27	100	—	—	—	Do.
10	Santa Clara School, Andalucia Street	1629	July 18	35	—	—	—	Do.
11	Antonio Rivera, near Tayuman	1674	July 20	22	—			Do.
12	Manrique Street, in front of Sampaloc Church	1665	June 13	40	—	—	—	Do.
13	Jesus and Narciso Streets, Pandacan	1438	June 25	400	—	—	—	Do.
14	Plaza Miranda, at Quiapo Church	1446	June 4	60	—	—	—	Do.
15	O'Donnell, between Lope de Vega and Zurbaran	1689	July 6	30	—	+	—	Do.
16	Anak Bayan, Paco	1599	July 9	3	—	—	—	Do.
17	Del Pan, San Nicolas	1630	July 19	5	—	—	—	Do.
18	Paco Market, Dart and Herran Streets	1675	June 21	4	—	—	—	Do.
19	Santa Ana Market, Calderon Street	1396	June 11	70	—	—	—	Do.
20	Engineer Island	1	Oct. 8	972	—	+	—	Do.
21	Plaza de la Virgen, Pandacan	2425	Aug. 12	32	—	—	—	Positive.
22	Mulate Market, at Leveriza Street	1658	May 17	50	—	+	—	Negative.

	CALOOCAN.							
C-1	Novaliches Road, between kms 10 and 11	----	Sept. 19	5				Do.
2	Balon bato, Novaliches Road, between kms 9 and 10	2487	Sept. 24	7	-			Do.
3	Cangcong Barrio, Novaliches Road, between kms 8 and 9	2576	Sept. 27	19	—	—	—	Do.
4	Rizal Avenue extension, between kms 6 and 7	1916	July 3	5	—	—	—	Do.
5	Balintawak, near km 9	895	Oct. 1	10	—	—	—	Do.
6	Novaliches Road, between kms 17 and 18	2505	June 18	40	—	—	—	Do.
7	Novaliches Plaza, between kms 17 and 18	916	Aug. 3	11	-	-	-	Do.
8	San Bartolome, Novaliches Road, between kms 16 and 17	925	Aug. 8	53	+	+		Do.
9	Baisa Barrio, Balintawak, between kms 12 and 13	950	Aug. 29	12	-	-	-	Do.
10	Mabini Street, near Sañgandaan	1472	June 6	5		-	-	Do.
11	Dulong Calzada, between kms 8 and 9	1867	July 25	16	-	-	-	Do.
12	Baisa Barrio, Balintawak, between kms 11 and 12	-------	Sept. 5	130	+	+	-	Do.
13	Novaliches Road, between kms 14 and 15	938	Aug. 20	130	—	—	—	Do.
14	A. Mabini, between kms 8 and 9	2478	Aug. 27	1	—	—	—	Do.
15	Sampalucan, A. Mabini, between kms 7 and 8	695	July 16	152	+	+	—	Do.
16	Talipapa, Balintawak, between kms 13 and 14	2571	Aug. 24	24	—	—	—	Do.
17	Caloocan Plaza, near municipal building	105	Sept. 17	30	—	-	—	Positive.
18	A. Mabini, Manila North Road, near km 9	683	Sept. 28	1	—	—	—	Negative.
19	A. Mabini, Manila North Road, near km 7	2469	Oct. 3	35	—		-	Do.
	SAN JUAN DEL MONTE.							
SJ-1	Mariquina Road, between kms 7 and 8	2354	Sept. 20	18	-	—	—	Do.
2	Corner Blumentritt and Bonifacio	-------	Aug. 28	920	+	+	-	Do.
3	Market place	878	May 23	50	-	—		Do.
4	Santa Lucia Barrio	1806	July 31	105	+	+	-	Do.
5	Rizal Street, near Burgos	-------	Sept. 9	3	-	—	-	Do.
6	Ermitaño Barrio, East Street	1744	Oct. 4	3	-	—	-	Do.
7	Mariquina Road, Ermitaño Barrio, between kms 8 and 9	-------	July 2	10	-	—	—	Do.
8	Broadway, near First Street, New Manila	-------	Sept. 23	6	-	—	—	Do.
9	Cubao Barrio, Mariquina Road, between kms 10 and 11	1812	Sept. 13	5	—	+	-	Do.
10	Ortega Street addition	2334	Aug. 2	10	—	—	—	Do.
11	San Pedro Street, near km 6, Mariquina Road	1780	Oct. 2	32	—	—	—	Do.

TABLE 1.—*Results of bacteriologic examinations of artesian water from wells in Manila and vicinity*—Continued

Tracing No.	Location.	Well No.	Date of collection of samples.	Number of colonies per cc.	Presumptive test.		*B. coli.*	Choleralike vibrios.
					1 cc.	10 cc.		
	SAN FELIPE NERI.		1929					
SF-1	Hagdaan Bato, Bonifacio Street	2535	Oct. 8	83	—	—	—	Positive.
2	T. Kalazan, near river	1636	Sept. 26	1	—	—	—	Negative.
3	Lamayan, corner Rizal and Vergara	872	Oct. 1	7	—	—	—	Do.
4	Blumentritt, between municipal building and school	859	Aug. 1	3	—	—	—	Do.
5	Mabini Street	1840	Sept. 10	43	—	—	—	Do.
6	Zanega Barrio	2527	Aug. 6	16	—	—	—	Do.
7	Jolo Barrio	2375	Aug. 19	590	—	—	—	Do.
8	Barranca	1664	Sept. 14	8	—	—	—	Do.
9	Hagdaan Bato, corner A. Luna and Bonifacio	863	Aug. 21	341	—	—	—	Do.
10	Kalentong Street, between kms 9 and 10	1832	Sept. 7	14	+	+	—	Do.
11	Jolo Barrio, at J. Coronado	1712	Aug. 23	9	+	+	—	Do.
12	Blumentritt, in front of market	798	July 30	5	—	—	—	Do.
13	Lamayan Barrio, Segura and Rizal Streets	2520	Sept. 25	6	—	—	—	Do.
	SAN PEDRO MAKATI.							
SP-1	Guadalupe, McKinley Road, between kms 7 and 8	1610	Aug. 7	4	—	—	—	Do.
2	McKinley Road, between kms 6 and 7	802	July 27	9	—	—	—	Do.
3	Guadalupe, 96 Street	1622	Aug. 22	3	—	—	—	Do.
4	Jose Rizal and P. P. Roxas	258	June 29	120	—	—	—	Do.
5	Olimpia Barrio, J. B. Roxas Street	786	Sept. 26	5	—	—	—	Do.
6	Bonifacio Street, 1 km east of municipal building	2052	Oct. 3	129	—	—	—	Do.
7	E. Zobel Street	814	Oct. 7	115	+	+	—	Positive.
8	Cristal Barrio, in front of chapel	1995	Oct. 5	12	—	—	—	Negative.
9	Masilang Barrio, Soliman, near Comercio	841	Sept. 24	13	—	—	—	Do.

10	Tejeron Barrio, McKinley Road, between kms 4 and 5	2013	Sept. 18	46		—	—	Do.
11	Culiculi Barrio, near Batangas railroad track	1445	Aug. 10	35	+	+	—	Do.
12	Guadalupe, in front of Dapitan Street	1601	Sept. 6	2	—	—	—	Do.
	PASAY.							
P-1	San Roque Barrio, corner Tolentino and Protacio	732	Aug. 30	3	—	—	—	Do.
2	Malibay Barrio, C. José Street, near chapel	877	Aug. 26	1	—	—	—	Do.
3	Santol Barrio, corner Protacio and Decena	765	Sept. 12	13	+	+	—	Positive.
4	Leveriza, near Villaruel		July 29	9	—	—	—	Negative.
5	Corner Tolentino and Aurora	768	Aug. 5	2	—	—	—	Do.
6	Zamora Street, corner Apelo Cruz, Tabon	444	July 26	23	—	—	—	Positive.
7	Tambo Barrio, at Camp Claudio		May 18	50	—	—	—	Do.

as long as the disinfectant is still present in the stored water. After the chlorine, for instance, has disappeared from a sample of water, the bacteria multiply rapidly.

The presumptive test is used as a preliminary test and as an indication of whether or not a further search for *B. coli* should be attempted. A positive presumptive test indicates that some sugar fermenters are present. *Bacillus coli* is only one of the many bacteria that ferment sugars. Consequently, not much significance should be attributed to this test, particularly when the colony count is low and the bacteria responsible for the fermentation are of the ærogenes group. It has been demonstrated that this group of bacteria in the Tropics is ubiquitous. They are present in places far remote from any possible fæcal pollution and this group of bacteria includes forms that are present in soil and vegetation, and which cannot be distinguished either by cultural or serologic methods from the same species encountered in fæces.(1)

On the other hand, it rarely happens, if ever, that true *B. coli* is isolated from water, nor is it found regularly in fæces of adult persons. A simple experiment showed us the difficulty of demonstrating true *B. coli* in water. We were repeatedly unable to demonstrate the presence of this bacterium in fishponds in which the fish population was thick and each fish examined contained true *B. coli* in the intestines, which could not be distinguished from *B. coli* of human origin, either by cultural or serologic reactions. The ubiquity of the representatives of the ærogenes group and the rare instances in which true *B. coli* is found in water weaken considerably the significance of the positive presumptive test and the negative *B. coli* test.

It has become a general practice to search for vibrios in waters in the Philippines where cholera is endemic and occurs to a more or less extent at regular intervals. Long years of experience taught us that cholera vibrios and choleralike vibrios will survive and multiply in water, particularly in sea water, for a long time.(2) Since artesian wells in the Philippines, particularly those in the lowlands along the shores, frequently contain salt, it was deemed advisable to test the water of artesian wells for vibrios in addition to the standard methods for water analysis.

Once the water becomes contaminated with the vibrios, they remain there alive for months. This fact may be utilized in sanitary water analysis as an anamnestic test. The contamination by surface water of artesian wells takes place most frequently

through the pump or the upper structure of the well. It is most likely to happen during the season of floods and rains. When vibrios get in the well under these circumstances, they will remain there for many months in spite of the fact that the colony count and the *B. coli* test may return to normal. The choleralike vibrios are different from true cholera vibrios, in two respects only; namely, they are not agglutinable by cholera serum, and when freshly isolated they are more strongly hæmolytic than freshly isolated cholera strains. They are coincident with true cholera vibrios in cholera fæces, which strongly indicates a close relationship between the two. Some vibrio strains isolated from waters could not be distinguished by cultural and serologic reactions from the choleralike vibrios isolated from convalescents and carriers.(2, 3, 4)

They can be, therefore, reasonably considered as an indication of fæcal contamination of various materials in cholera-endemic countries. Their regular increase in the fæces of a population immediately before the outbreak of cholera stamps them as greatly significant from the sanitary and epidemiologic standpoint. They may be found in waters and other materials such as food, vegetables, and drinks and can be demonstrated with far greater technical ease than any other intestinal pathogenic bacteria, due to their tolerance to alkaline reaction and on account of the enrichment process which allows them to overgrow other bacteria present in the material examined. We have, therefore, in the test for vibrios a very sensitive method for detecting fæcal pollution. Another advantage of this test for choleralike vibrios lies in the fact that it enables us to decide whether the well in question is being continuously contaminated or whether the contamination was caused by extraordinary circumstances, such as flood, poor mechanical condition of the pump, or improper protection of the head of the well, etc. If the contamination of the well is not continuous, the vibrios will disappear promptly after proper repairs have been made and after the well waters and the pump are disinfected with formalin. Should there be a permanent contamination through underground leakage, the vibrios will reappear repeatedly after the effect of the disinfectant has ceased.

CONCLUSION

In general, the artesian wells in Manila and vicinity supply water that meets the requirements of the standard for drinking waters. Whenever artesian wells show contamination, a

thorough examination of the mechanical parts of the well, proper repair of the pump, and proper protection of surroundings and thorough disinfection will assure further usefulness of the well. In the test for vibrios, we have an additional method, a very sensitive one, for detection of fæcal pollution that is useful in cholera endemic countries.

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SPLEEN SURVEY OF THE EASTERN SHORE OF BATAAN PROVINCE, LUZON

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ONE TEXT FIGURE

Contemplated maneuvers of the Philippine Division made it necessary to survey the eastern shore of Bataan Peninsula, Luzon, to determine the prevalence of malaria along the proposed line of march of this division. Because of the relatively large area to be surveyed and the limited time within which the survey was to be accomplished, it was determined that a spleen survey, together with location of breeding places and identification of mosquitoes and larvæ, would furnish the information necessary.

Simmons, St. John, and Reynolds(1) have shown that splenomegaly in children is an excellent index of the prevalence of malaria in a community of Filipinos. In Fort Stotsenburg they found that 91 per cent of cases showing palpable spleens were suffering from malaria, while the same class of persons on Corregidor Island showed a positive finding of malaria in 52 per cent of cases. The percentage of positive cases rose sharply with the increased size of the spleens.

Bataan Peninsula forms the western boundary of Manila Bay, separating that body of water from the China Sea and forming the northwestern boundary of the North Channel entrance to Manila Bay. It is about thirty miles long and averages about ten miles in width. In the south of the peninsula are the Mariveles Mountains, an extension of the Zambales Range of the north. Between the two ranges is a pass which allows free communication between the east and west coasts. The east coast consists of a flat plain of volcanic sand traversed by a large number of small rivers flowing from the mountains into Manila Bay. Most of the shore line is swampy. This portion

of the peninsula is inhabited by Tagalogs and Pampangos. There are no Caucasians. The eastern coastal plain varies in width from one-half mile to as much as seven or eight miles. The capital is Balanga, situated about midway the length of this plain, the population being about eight thousand. The population of the peninsula is about sixty thousand, about half of which live on the eastern shore where they are engaged in fishing and raising sugar cane. There are many fishponds in this area, which fact has an important bearing upon the mosquito population.

The survey party consisted of two doctors, two Filipinos trained in the collection and identification of adult mosquitoes and their larvæ, and a white sergeant whose duty it was to superintend the work of the field portion of the survey. Three days sufficed for the survey.

Permission was obtained from the Bureau of Education to examine school children in the towns of Dinalupihan, Hermosa, Orani, Samal, Abucay, Capitangan Barrio, Balanga, Cupang Barrio, Orion, and Limay. These centers of population in the order named, as will be noted on the map, are situated on the eastern plain from north to south. It was decided that the best procedure was to examine all the children in the first grade of each school visited. This would give a fairly complete cross section of the population and would provide a fairly accurate index of the rate of malarial infection in the whole population. The younger children were selected because rigidity of the abdominal muscles in the older groups interfered with palpation of the spleen.

Since attendance at school is voluntary it is certain that a rather high percentage of the older children did not attend school but inquiry indicated that a rather large percentage of the low age group did attend.

For the purpose of indicating the size of the splenic enlargement it was decided that all cases not palpable were to be called negative. If only palpable at the rib margin they were to be called P. I.; that is, palpable on inspiration. For spleens of larger dimensions the area on the abdominal wall between the symphisis pubis was divided into four parts by imaginary horizontal lines passing midway between the costal margin and the umbilicus, through the umbilicus, and midway between the umbilicus and the symphisis.(2) Spleens, the margins of which were found in the areas above outlined, were numbered 1, 2, 3,

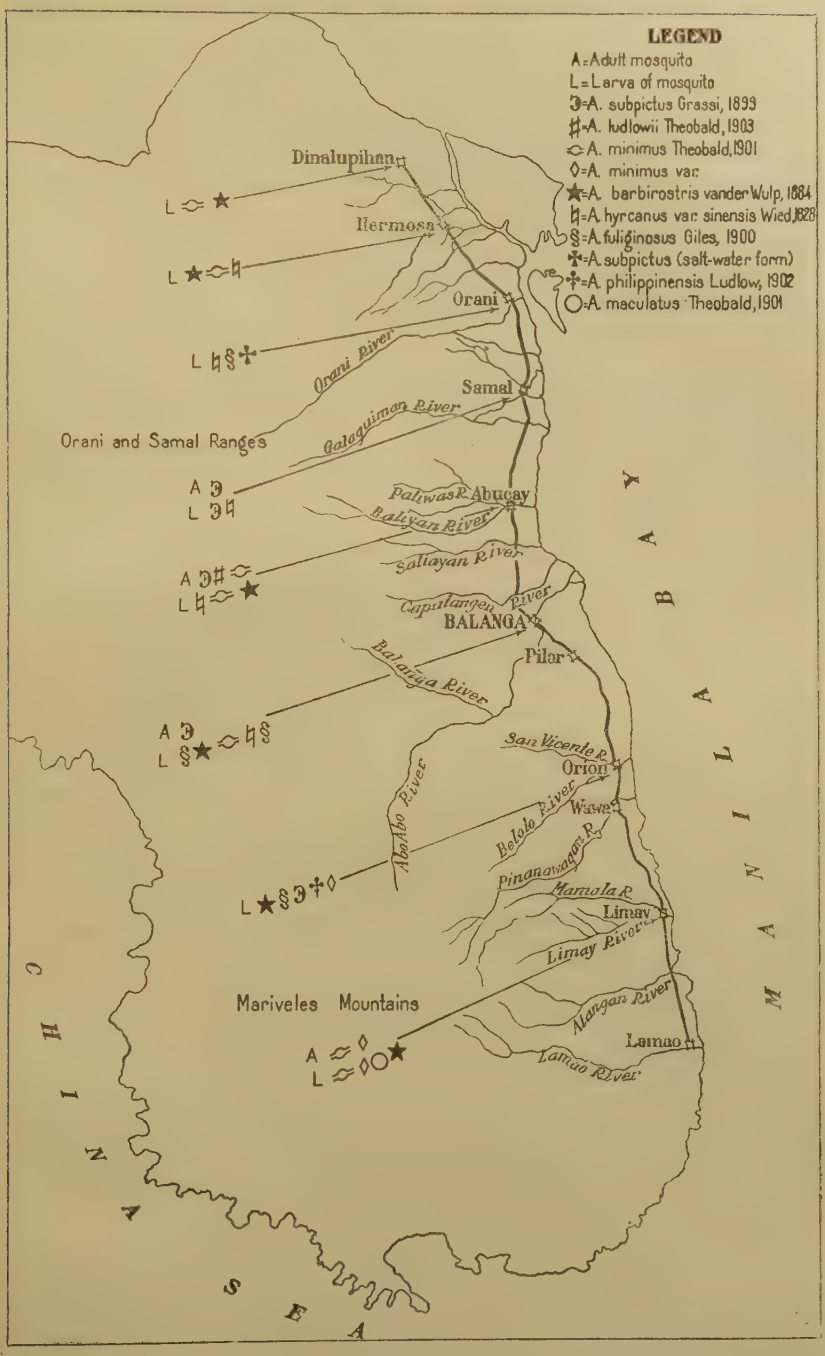

Fig. 1. A part of Bataan Province, Luzon, showing localities in which collections of mosquitoes were made.

and 4 from above downward. Thus, a No. 1 spleen was larger than a P. I. spleen but smaller than a No. 2.

Examination was made during full inspiration with the child lying on its back, knees flexed and hands folded on the chest. All examinations were made without the intervention of clothing. This was made easy by the scanty clothing worn by the children.

TABLE 1.—*Spleen survey.*

Town.	Sex.	Children examined.	P. I. spleens.	No. 1 spleens.	No. 2 spleens.	Per cent positive.	Total per cent.
Dinalupihan	M	16	4	0	2	37.5	30.5
	F	20	3	1	1	25	
Hermosa	M	68	2	0	1	4.4	7
	F	59	4	1	1	10	
Orani	M	69	2	1	0	4.3	5.5
	F	75	4	1	0	6.6	
Samal	M	55	3	0	0	5.4	6.5
	F	52	4	0	0	7.6	
Abucay	M	65	2	1	1	4.6	3.9
	F	37	1	0	0	2.7	
Capitangan Barrio	M	14	1	0	0	7.1	7.7
	F	12	1	0	0	8.3	
Balanga	M	66	5	0	3	12	11
	F	51	3	0	2	13	
Cupang	M	31	2	1	0	9.6	9.6
	F	0	0	0	0	0	
Orion	M	87	7	3	1	12.6	12
	F	65	4	2	1	10.7	
Limay	M	27	4	4	0	29	23
	F	29	4	1	0	17	

TABLE 2.—*Mosquitoes collected during the survey.*

Place.	Date.	Species.	Sex. ♂	Sex. ♀	Remarks.
Samal	Nov. 4, 1930	*A. subpictus* fresh-water form	1		Captured among grasses.
Abucay	Nov. 5, 1930	do	2	1	Captured along the sides of the river banks.
		A. ludlowii Theobald 1903	3	2	
		A. minimus Theobald 1901 (*M. mangyana* Banks 1906. Probably *M. febrifera* Banks 1914).		1	
Balanga	Nov. 5, 1930	*A. subpictus*	1		Captured in house.
Limay	Nov. 6, 1930	*A. minimus* Theobald 1901	3		Captured along the sides of the river banks.
		A. minimus var. *filipinæ* (Possibly *A. aconitus* Donitz 1902.)	1		

TABLE 3.—*Mosquito larva survey.*

Place.	Date collected.	Lot No.	Species.	Larvæ.	Remarks.
	1930				
Layac, Dinalupihan	Nov. 3	19	*A. minimus* Theo. 1901 (*M. mangyana* Banks 1906. Probably *M. flavirostris* Ludl. 1913. Probably *A. febrifera* Banks 1914).	10	River, flowing, deep. Some bamboo roots, grasses, and débris.
			A. barbirostris Van der Wulp 1884	11	
Hermosa	Nov. 4	1	----do	1	Fresh, flowing, clean water.
			A. minimus Theo. 1901	1	Débris and grasses.
Do	Nov. 4	2	Unidentified dead larvæ	3	Fresh, polluted, and flowing water.
Do	Nov. 4	3	*A. hyrcanus* var. *sinensis* Wied. 1828.	2	Fresh, still water, kiapo.
			----do	1	Fresh water, kiapo.
Orani	Nov. 4	4	*A. fuliginosus* Giles 1900 (*Chagasia lineata* Ludl. 1908 and *Kertesia mcgregori* Banks 1909).		
Do	Nov. 13	20	*A. subpictus* salt-water form (probably var. *indefinitus* Ludl. 1904).	144	Fishpond, salt water. Some chara and algæ.
			Unidentified larvæ (dead)	21	
			Pupæ	45	
Do	Nov. 13	21	*A. subpictus* (salt water)	48	Small pool, salt water.
			Unidentified dead larvæ	43	Some grasses.
			Pupæ	1	
Do	Nov. 13	22	*A. subpictus* (salt water)	173	Canal with still, salt water. Some grasses.
			Unidentified larvæ (dead)	59	
Do	Nov. 13	23	*A. subpictus* (salt water)	49	Fishpond, salt water. Some chara and algæ.
			Unidentified dead larvæ	16	
			Pupæ	27	
Samal	Nov. 5	5	*A. subpictus* Grassi 1899 (fresh water form).	3	Along sides of a canal.
			Unidentified dead larvæ	13	Fresh, still water with algæ.
Do	Nov. 5	6	*A. subpictus* (fresh water)	13	Fresh marsh water with algæ.
			Unidentified dead larvæ	7	
Do	Nov. 5	7	*A. hyrcanus* var. *sinensis*	1	Fresh and flowing water with grasses and kiapo.
Abucay	Nov. 5	8	*A. hyrcanus* var. *sinensis*	9	Along sides of a canal.
			Unidentified dead larvæ	11	Fresh, flowing, dirty water with grasses and débris.
Do	Nov. 5	9	*A. minimus* Theo. 1901	10	River, flowing, fresh, clean, shady; some grasses and débris.
			A. barbirostris	3	
			Unidentified dead larvæ	4	

TABLE 3.—*Mosquito larva survey*—Continued.

Place.	Date collected.	Lot No.	Species.	Larvæ.	Remarks.
	1930				
Abucay	Nov. 5	10	Unidentified dead larvæ	2	Small pool, fresh water.
Balanga	Nov. 5	11	*A. fuliginosus*	5	Fresh, still water with kiapo and grasses.
			Unidentified dead larvæ	2	
Cupang, Balanga	Nov. 5	12	*A. barbirostris*	9	Along sides of a canal with fresh, flowing and clean water. Some grasses and débris.
			A. minimus Theo. 1901	1	
			Unidentified dead larvæ	6	
Do	Nov. 5	13	*A. hyrcanus* var. *sinensis*	2	Fresh, still water with kiapo and grasses.
			A. fuliginosus	1	
			Unidentified dead larvæ	6	
Orion	Nov. 5	14	*A. barbirostris*	5	Do.
			A. fuliginosus	1	
			Unidentified dead larvæ	3	
Do	Nov. 5	15	*A. subpictus* (fresh water)	69	Small pool with fresh water.
			Unidentified dead larvæ	34	Some algæ.
Do	Nov. 5	16	*A. barbirostris*	8	Along sides of canal. Fresh flowing water. Some algæ, kiapo, chara, and grasses.
			A. fuliginosus	20	
			A. philippinensis Ludl. 1902.	2	
			A. minimus var. (possibly *A. aconitus* Donitz 1902.	1	
			A. subpictus (fresh water)	1	
			Unidentified dead larvæ	5	
Do	Nov. 6	17	*A. subpictus* (fresh water)	11	Fresh, still water with algæ.
			Unidentified dead larvæ	4	
Limay	Nov. 6	18	*A. minimus* Theo. 1901	9	Along sides of a rocky river with clean flowing and partly shaded water. Some bamboo roots, grasses, algæ, and débris.
			A. minimus var. *aconitus*	23	
			A. maculatus Theo. 1901	1	
			A. barbirostris	5	
			Unidentified dead larvæ	19	

Eight hundred ninety-eight children were examined, of which there were five hundred two males and three hundred ninety-six females.

Of the five hundred two males eighty-one were over 9 years of age and four hundred twenty-one were between 6 and 9 years of age.

Of the three hundred ninety-six females thirty-seven were over 9 years of age and three hundred fifty-nine were between 6 and 9 years of age.

Total children over 9 years of age, one hundred eighteen. Total children between 6 and 9 years of age, seven hundred eighty.

The preceding tables show the results of the survey.

CONCLUSIONS

No spleen larger than a No. 2 was found during the survey. Several striking features are evident—one is that the nearer the town is located to the foothills of the mountains the higher is the splenic rate. This is particularly noticeable in Dinalupihan, with a splenic rate of 30.5 per cent and in Limay with a splenic rate of 23 per cent, these two towns being the only two of those noted in Table 1 that are situated directly in the foothills. Without exception cases found at towns other than these two resided in the interior of the peninsula and not on the coastal plain. From this fact we are led to conclude that malaria does not exist on the eastern coastal plain of Bataan except as imported from the foothills.

Anopheles ludlowii is commonly encountered in the salt-water marshes of this region, but is not a vector of malaria in this locality. Our mosquito and larva survey was confined to an attempt to determine the presence or absence of *A. minimus* in this region. While this mosquito was found in Hermosa, Abucay, Cupang, and Limay, it is apparent that it is not an effective vector of malaria in any of these localities, except Limay, since the population did not show any considerable splenic index. The population of Dinalupihan showed plainly the presence of malaria in a considerable percentage of the residents, although the intensity of the infection was not great.

These findings are in sharp contrast with the work of Ash in 1922 who examined cases at all the towns mentioned and found only two positive spleens in one hundred ninety-one cases examined. We are inclined to believe that the discrepancy is due to the fact that there is a much greater attendance of school children from the foothills than there was eight years ago and that there is no actual increase in malaria except in cases residing off the coastal plain.

NOTE

The classification of the anophelines used in this article is that of Dr. W. V. King. This classification is of temporary character.

Grateful acknowledgment is made of valuable assistance rendered in this survey by Serg. Lloyd Stevens, Medical Depart-

ment, United States Army; Mr. Domingo Santiago, field inspector for malaria investigations, Bureau of Science; and Private 1st class Bonifacio Reyes, Medical Department (PS), United States Army.

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1. SIMMONS, JAMES S., JOE H. ST. JOHN, and FRANCOIS H. K. REYNOLDS. A malarial survey at Ft. Stotsenburg, P. I. Mil. Surg. 67 (July, 1930) 1–13.

2. HACKETT, L. W. Malaria control through anti-mosquito measures in Italy. Trans. R. S. of Trop. Med & Hyg. 22 (1929) VI, 480.

ILLUSTRATION

TEXT FIG. 1. Map of a part of Bataan Province, Luzon, showing localities in which collections of mosquitoes were made. 219

FURTHER EXPERIMENTS CONCERNING IMMUNITY IN TREPONEMATOUS INFECTIONS [1]

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ONE TEXT FIGURE

The experiments given in this communication were undertaken for the purpose of extending previous findings made on Philippine monkeys concerning homologous immunity to yaws, cross immunity between syphilis and yaws, and immunity to yaws resulting from immunization with yaws and syphilis vaccine. This investigation, therefore, treats of the same problems as those presented in our published experiments.

ADDITIONAL EXPERIMENTAL EVIDENCE SHOWING THAT INFECTION WITH SYPHILIS IMMUNIZES PHILIPPINE MONKEYS AGAINST YAWS

A somewhat different experimental procedure was adopted in this experiment than in previous ones dealing with this question.[2] Instead of intradermal inoculation with syphilis, as previously employed, intratesticular or intramuscular inoculation with syphilis was used in this experiment. Thus an infection with syphilis was produced in the monkeys that was different from the infection produced in former experiments in so far as syphilitic lesions on the integument did not develop in the monkeys included in the present experiment.

Through this experiment it was intended to prove the correctness of previous findings and to obtain information on whether or not cross immunity to yaws develops in syphilitic monkeys under such conditions of experimental inoculation, which is different from the natural way that the syphilitic infection invades the fully susceptible human body tissues but which may be reasonably expected to occur at times in partially immune cases upon reinfection following cure.

[1] Received for publication February 5, 1931.

[2] Philip. Journ. Sci. 43 (1930) 583.

As was to be expected, the inoculation with syphilis of Philippine monkeys did not produce generalized manifestations. The treponemas remained lodged in the tissues where they were placed by the injection and wandered into the lymphatics without producing clinical manifestations. Consequent to the mesodermotropic proclivity of the treponema of syphilis, the cross immunity developed about the same time in those cases in which intradermal inoculation was employed and primary syphilitic skin lesion developed as it did in the present experiment, when inoculation was performed into the mesoderm.

One monkey infected with syphilis by intratesticular inoculation was found susceptible to yaws six months after the inoculation with syphilis. Two others inoculated in the same way and one inoculated also with syphilis but by intramuscular injection were found immune to yaws when inoculated ten and again eleven months after the first inoculation with syphilis.

The serologic findings in these animals are interesting. In the absence of initial skin lesions the early serologic response to inoculation with syphilis was absent in all the animals tested; the late response, on the other hand, was as strong as the one observed in syphilitic monkeys with initial skin lesions (Fig. 1).

Guided by our previous observation that the high degree of group immunity in experimental treponematoses sets in at the time when the late serologic response has reached the highest point and has remained there, we have timed the tests for immunity to yaws accordingly in the last three monkeys used in this experiment (see table 1).

CONCLUSIONS

1. Syphilitic infection conveyed to Philippine monkeys by intramuscular or intratesticular inoculation without formation of apparent lesions, either initial or generalized, immunizes these animals against cutaneous inoculation with yaws.

2. Due to mesodermotropic preference of the parasite of syphilis, the cross immunity to yaws in Philippine monkeys inoculated with syphilis under these conditions developed about the same time as it did when monkeys were infected by intradermal inoculation with syphilis and when initial skin lesions developed.

3. The results of this experiment confirm those obtained in former experiments [3] concerning immunologic reciprocity between syphilis and yaws.

[3] Philip. Journ. Sci. 43 (1930) 583.

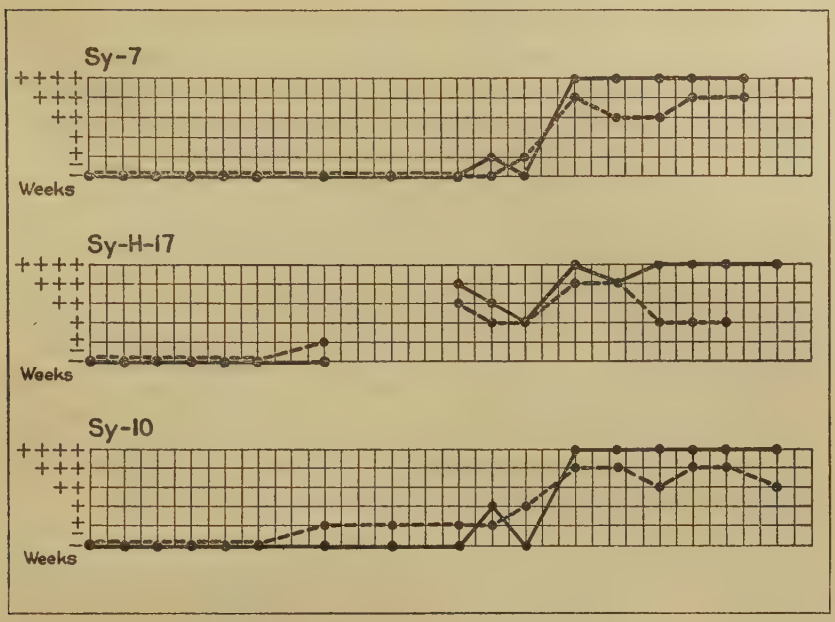

FIG. 1. Showing the serologic response to intramesodermal infection with syphilis in Philippine monkeys.

EXPERIMENTAL EVIDENCE SHOWING THAT MESODERMAL INOCULATION WITH YAWS IMMUNIZES AGAINST EPIDERMAL INFECTION WITH YAWS

This experiment with yaws was arranged in a similar way to the preceding one with syphilis. Two monkeys were inoculated with yaws by intramuscular injection and one by intratesticular injection. One control was inoculated intradermally with the same amount of the same yaws inoculum to test the viability of the treponemas. While the animals that were inoculated by intramuscular and intratesticular inoculation did not develop clinical yaws lesions, the control animal inoculated by intradermal injection developed typical yaws showing that the inoculum contained viable treponemas. The test for immunity by intradermal inoculation with yaws was performed three and four months after the mesodermal infection, that is, four and three months earlier than immunity to yaws develops in Philippine monkeys following epidermal inoculation with yaws. The test for immunity was confirmed. Normal control animals were included in the test for immunity (see table).

The result of this experiment shows that inoculation with treponema of yaws placed in the mesoderm in such a manner that no clinical yaws lesions develop, immunizes monkeys against

subsequent intradermal infection with yaws in a much shorter time than the intradermal inoculation that is followed by development of specific lesion. The yaws immunity develops after mesodermal inoculation just as quickly as it does after generalization of the yaws process in Philippine monkeys.

CONCLUSION

This experiment confirms and amplifies our previous findings [4] that intramesodermal inoculation with yaws without skin lesion confers immunity to yaws much earlier than does intradermal inoculation followed by development of cutaneous lesions.

AN EXPERIMENT CONCERNING PREVENTIVE IMMUNIZATION WITH LIFELESS SYPHILIS AND YAWS VACCINE

This experiment offers additional evidence to prove that preventive vaccination against treponematoses has a decided effect on the course of subsequent infection.[5]

Two monkeys (K–33 and K–34) received two subcutaneous injections of syphilis vaccine (Nichols' strain), rich in treponemas and heated at 60° C. for 30 minutes. The first vaccination was given on December 9, 1929, and the second, eight days later. On April 24, 1930, both animals were each given one subcutaneous injection of yaws vaccine, killed by heating to 60° C. for one hour.

On June 3, 1930, the two vaccinated animals, together with one normal control animal were inoculated by intradermal injection with the same amount of yaws inoculum on both eyebrows. The intradermal inoculation with living yaws material was performed six months after the first vaccination with killed syphilis vaccine and about six weeks after the last vaccination, that is, with the killed yaws vaccine.

On June 23, that is three weeks after the inoculation, the control monkey developed typical clinical yaws at the places of inoculation. These lesions ran a typical course and contained numerous treponemas.

The two vaccinated monkeys were observed for a period of more than six months after the inoculation. Monkey K–33 did not show any sign of lesion and monkey K–34 developed a dry desquamative lesion on one eyebrow in which no treponemas were found on repeated examinations. The lesion develop-

[4] Philip. Journ. Sci. 35 (1928) 295.
[5] Philip. Journ. Sci. 42 (1930) 219.

ed July 28, 1930, and was completely healed on August 25 of the same year.

The vaccination with killed vaccine in this experiment had the effect that upon subsequent inoculation one animal developed no lesion at all, while the other of the two vaccinated monkeys showed no lesion at one point of inoculation and a short lived desquamative framboeside without demonstrable treponemas at another point of inoculation; a lesion which we found in partially immune monkeys as the last outcrop of generalized dissemination [6] and in experimental human volunteers as a result of superinfection at the place of superinoculation which was performed in the late part of the secondary stage,[7] that is at a time when a considerable degree of immunity has developed in the course of yaws infection.

CONCLUSIONS

1. Preventive immunization with killed syphilis and yaws vaccine confers a high degree of antitreponematous immunity to normal Philippine monkeys.

2. The immunologic reciprocity between syphilis and yaws is again evident from the results of this experiment.

3. The result of this experiment is in agreement with those of our previous ones concerning preventive vaccination and vaccine-therapy.[8]

AN EXPERIMENT SHOWING THE IMMUNOLOGIC EFFECT OF MESODERMAL REINFECTION WITH YAWS PERFORMED AFTER SPECIFIC TREATMENT HAS BEEN GIVEN IN THE EARLY STAGE OF INITIAL YAWS LESION

Two Philippine monkeys were inoculated simultaneously with the same amount of the same yaws inoculum by intradermal injection, July 23, 1930. Four weeks after the inoculation typical papular lesions containing treponemas, developed in both animals. Neosalvarsan treatment was given September 2, 1930. The lesions healed in a week after the first therapeutic injection. September 30, 1930, one of the monkeys (Le. No. 1) was reinoculated with yaws by intramuscular injection. The animals were inspected weekly and no sign of yaws was found from the time the animals were cured. November 3 both monkeys were inoculated simultaneously on both eyebrows by intradermal injection with the same amount of the same yaws

[6] Philip. Journ. Sci. 35 (1928) 231.
[7] Philip. Journ. Sci. 30 (1926) 463.
[8] Philip. Journ. Sci. 42 (1930) 219; 43 (1930) 603.

inoculum as a test for immunity. December 2, that is, four weeks after the last intradermal inoculation, an oozing typical lesion containing treponemas was found on both eyebrows of monkey K–35. This animal was treated in the early stage of initial yaws and received no further inoculation. The other yaws monkey of this experiment (Le. No. 1), which was similarly treated but was reinfected by intramuscular injection of living yaws treponemas subsequent to specific cure, developed no lesion at the place of the last intradermal inoculation with yaws performed as a test for immunity. A confirmatory test for immunity was performed on December 24 of the same year and the viability of the inoculum was tested on one normal control monkey. This test confirmed the result of the previous test.

SUMMARY

Two Philippine monkeys inoculated by intradermal injection with yaws were treated with neosalvarsan in the early stage of initial yaws. One of the two animals received an intramuscular injection of living treponemas of yaws ten weeks after the original inoculation with yaws and following the treatment. Both animals were subjected to a test for immunity by intradermal inoculation with yaws four months and one week after the original inoculation with yaws. The animal that was reinfected with yaws by intramuscular injection proved to be immune, while the other yaws monkey that was similarly treated but not reinfected was found susceptible at that time. Confirmatory test confirmed the previous test (see Table 4).

CONCLUSIONS

1. Intramesodermal incorporation of treponema-antigen performed on early cured yaws monkeys hastens the development of antitreponematous immunity. It prevents subsequent reinfection and consequently it prevents the development of subsequent stages of the treponematous infection.

2. While intradermal superinfection with yaws does not accelerate the immunity induced by the primary lesion in the course of an infection, intramesodermal superinfection with yaws, like the generalization of yaws (the secondaries), or like vaccine-therapy, or like a superinfection with mesodermotropic treponema of syphilis, accelerates the development of immunity to yaws.

3. The result of this experiment confirms our previous findings concerning vaccine-therapy in treponematous infections.[9]

[9] Philip. Journ. Sci. 43 (1930) 603.

TABLE 1.—*Showing the result of intradermal inoculation with yaws performed on Philippine monkeys that have been infected with syphilis by intratesticular or intramuscular injection.*

[+, lesion; —, no lesion; 0, not done.]

Designation of monkey.	Inoculated with syphilis.		Inoculated with yaws.		Result.
	Date.	Mode.	Date.	Mode.	
Sy–2	[a] V–24–28	Intratesticular	XI–13–28	Intradermal	+
Sy–7	V–15–29	do	III–24–30	do	—
	VI–28–29	do	IV–21–30	do	—
	V–15–29	do	III–24–30	do	—
Sy–H–27			IV–21–30	do	—
Sy–10	V–15–29	Intramuscular	III–24–30	do	—
	VI–28–29	do	IV–21–30	do	—
Yac–23 Control	0		III–24–30	do	+
Yac–24 Control	0		IV–21–30	do	+

[a] These letters and figures indicate month, day, and year; thus, V–24–28 means May 24, 1928.

TABLE 2.—*Showing the rapid development of yaws immunity following intramesodermal inoculation with yaws.*

[+, lesion; —, no lesion; 0, not done; ?, no lesion; D, died.]

Designation of monkey.	Inoculated with yaws.			Inoculated with yaws (test for immunity).			Remark.
	Date.	Mode.	Result.	Date.	Mode.	Result.	
Ya intramuscular No. 1	[a] III–13–30	Intramuscular	?	VI– 5–30	Intradermal	—	D VII–22–30.
Ya intram No. 2	III–13–30	do	?	VII– 8–30	do	—	
				X–30–30		—	
Ya intratest L No. 2	III–13–30	Intratesticular	?	VII– 8–30	do	—	
				X–30–30		—	
Ya–C–22	III–13–30	Intradermal	+				
Ya–C–29	0			VI– 5–30	do	+	
Ya–C–32	0			VII– 8–30	do	+	
Ya–Control	0			X–30–30	do	+	

[a] These letters and figures mean month, day, and year; thus, III–13–30 means March 13, 1930.

TABLE 3.—*Showing the results of inoculation with yaws performed on monkeys immunized with killed syphilis-yaws vaccine.*

[+, positive take, treponemas present; —, negative take, treponemas not found; ±, frambœside; v, vaccine.]

Designation of monkey.	Vaccinated subcutaneously with 60° C. vaccine.			Inoculated with yaws (test for immunity).		
	Syphilis vaccine.		Yaws vaccine.	Date.	Result.	Treponemas.
K–33	[a] XII– 9–29	XII–17–29	IV–24–30	VI– 3–30	—	—
K–34	XII– 9–29	XII–17–29	IV–24–30	VII– 1–30	±	—
Ya–C–28	0	0	0	VI– 3–30	+	+
Ya–C–30	0	0	0	VII– 1–30	+	+

[a] These letters and figures mean month, day, and year; thus, XII–9–29 means December 9, 1929.

TABLE 4.—*Showing the immunologic effect of intramesodermal inoculation with yaws performed after specific treatment given in the early stage of initial yaws.*

[+, positive take; —, negative take; 0, not done.]

Designation of monkey.	Inoculated with yaws (intradermal).		Specific treatment.	Inoculated with yaws (intramuscular).	Intradermal test for immunity to yaws.	
	Date	Result.			Date.	Result.
Le-No. 1	[a]VII-23-30	+	IX-20-30	IX-30-30	XI-3-30	—
					XII-24-30	—
K-35	VII-23-30	+	IX-20-30	0	XI- 3-30	+
Ya-C-38 Control	0		0	0	XII-24-30	+

[a] These letters and figures mean month, day, and year; thus, VII-23-30 means July 23, 1930.

ILLUSTRATION

TEXT FIG. 1. Chart showing the serologic response to intramesodermal infection with syphilis in Philippine monkeys.

PHILIPPINE TURPENTINE FROM PINUS INSULARIS (ENDLICHER)

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and

J. FONTANOZA

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TWO PLATES

The Benguet pine (*Pinus insularis* Endlicher) forms extensive forests in the mountain regions of northern Luzon. Recently we investigated samples of resin tapped from the Benguet pine, and our results showed that an excellent quality of turpentine of high pinene content is obtained from it.

Turpentine consists essentially of a mixture of terpenes. Alpha pinene, which may be separated from turpentine by distilling is, at present, the chief source of synthetic camphor.[1]

Turpentine is used principally for paint and varnish thinners. More than 80 per cent of the total output is used for this purpose. It is also used in the manufacture of shoe polish, leather dressing, automobile oils and greases, sealing wax, and pharmaceutical and chemical supplies.

During the year 1928 a total of more than 5,000,000 gallons of turpentine was consumed [2] in the United States, and over 14,000,000 gallons was exported.[3]

Information concerning the cultivation of pine trees and the production and uses of turpentine is given by various Government publications such as farmers' bulletins on longleaf pine, slash pine, and pine nursery stock.[4]

[1] Journ. Ind. Eng. Chem. News Ed. 8 (1930) 8.

[2] Chem. Met. Eng. 37 (1930) 196.

[3] Yearbook U. S. Dept. Agr. 1930, 944.

[4] Mattoon, W. R., U. S. Dept. Agr. Farmers' Bull. 1256 (1922); 1486 (1926).
Wakeley, P. C., U. S. Dept. Agr. Leaflet 32 (1929); 35 (1929).
Wyman, L., Florida Dept. Agr. Bull. 25 N. S. (1929).
Hayes, R. W., and P. C. Wakeley, Louisiana State Univ. Bull. 21 N. S. No. 3, pt. 2 (1929).
Veitch, F. P., and V. E. Grotlisch, U. S. Dept. Agr. Bull. 898 (1920).

Recently, there have appeared two articles [5] that give a very good resumé of the present status and future prospects of the turpentine industry.

In 1929, more than 79,000 kilograms of turpentine, valued at over 26,000 pesos, were imported into the Philippines.[6] Most of this came from the United States.

Turpentine obtained from the resin of Benguet pine trees has been investigated by Richmond [7] and also by Brooks.[8] The trees selected for their investigations were growing near Baguio, a summer resort situated at an elevation of about 1,500 meters in the mountain province of the Philippines. Their results showed that some of the trees gave fair yields of turpentine while others gave rather poor yields. According to Brooks, turpentine from the Benguet pine trees consists principally of pinene and compares favorably with American turpentine.

EXPERIMENTAL PROCEDURE

Since these preliminary investigations, carried out some years ago, gave promising results it seemed desirable to continue this work.

During the spring of 1930, J. Fontanoza and P. D. Esguerra, foresters of the Philippine Bureau of Forestry, tapped a number of Benguet pine trees in and near Baguio. The resin obtained from these trees was then shipped to the Bureau of Science laboratories in Manila where we made an investigation of it.

In Table 1 are given the location and the approximate diameter of the pine trees selected for this investigation. The dates of tapping the trees, the number of chippings, and the yield of resin obtained are also included. As shown by the data, trees of various sizes were selected for our experiments.

The cup and gutter method was employed by the foresters in tapping and chipping the pine trees. The procedure was essentially the same as that described some years ago by Herty [9] except that somewhat different kinds of tools were used. For

[5] Speh, C. F., Journ. Chem. Ed. 7 (1930) 2322.
Bent, L. N., Journ. Chem. Ed. 7 (1930) 2365.
[6] Annual Report, Insular Collector of Customs, Manila, (1929).
[7] Philip. Journ. Sci. § A 4 (1909) 231.
[8] Philip. Journ. Sci. § A 5 (1910) 229.
[9] U. S. Dept. Agr. Forest Service Bull. 40 (1903) 17.

TABLE 1.—*Location and diameter of Philippine trees selected for collecting Benguet pine resin.*

Tree No.	Location.	Diameter.[a]	Date of tapping.	Duration of chipping.	Number of chippings.	Yield of resin.
		cm.	1930.	1930.		*g.*
1	Forbes Park	40.5	Jan. 22	Jan. 29 to July 30	27	574.0
2	do	37.0	do	do	27	505.6
3	do	37.5	do	do	27	1,898.0
4	do	33.5	do	do	27	882.8
5	do	48.5	do	do	27	1,220.6
6	do	57.5	do	do	27	1,346.5
7	Irisan, near Naguilian Road.	42.5	Feb. 10	Feb. 17 to July 31	27	1,137.9
8	do	41.0	do	do	27	883.2
9	do	35.5	do	do	27	1,779.5
10	do	34.0	do	do	27	975.4
11	do	46.0	do	do	27	2,463.6
12	do	57.0	do	Feb. 17 to July 30	35	2,448.3
13	do	38.0	do	do	35	1,753.1
14	do	47.0	do	do	35	1,338.6
15	do	42.0	do	do	35	1,471.4
16	do	51.0	do	do	35	3,037.3
17	Pimmarioc, Trinidad	42.0	Apr. 25	May 2 to July 29	34	1,123.6
18	do	62.0	do	do	34	3,683.1
19	do	64.5	do	do	34	1,001.6
20	do	61.0	do	do	34	1,136.8
21	do	66.0	do	do	34	917.4

[a] The diameters of the trees were measured at a height of 1.3 meters from the ground.

instance, instead of using a broad ax, a heavy bolo served the same purpose. After the first cut (streak) is made in the trees most of the resin usually flows out during the first day and very little is obtained during the next few days. When the first cut is extended by a second chipping the resin begins to flow freely again for another day. By making new chippings frequently and continually lengthening the original cut the tree continues to yield resin for some months. A day or so after a new chipping, when the exudation had practically stopped, the resin was poured (dipped) from the tree cup into a permanent container.

As shown by the data (Table 1) the yield of resin from individual trees varies considerably.

Altogether twenty-one trees were tapped. The total resin obtained from the first tapping of these trees was combined into a composite sample (composite No. 1). Subsequently a number of these trees were tapped a second time. When these various

samples of pine resin were received in our laboratory in Manila, they were first steam distilled to separate the turpentine from the rosin. After distillation the turpentine was separated from the admixed water and dried with calcium chloride. After draining off the water the rosin was dried in desiccators. The percentage yields of turpentine and rosin obtained from the pine resin are given in Table 2.

TABLE 2.—*Turpentine and rosin obtained from Benguet pine trees.*

Sample.[a]	Turpentine.	Rosin.
	Per cent.	*Per cent.*
Tree No. 3	15.33	84.67
Tree No. 5	17.02	82.98
Tree No. 9	16.18	83.82
Tree No. 18	17.47	82.53
Composite No. 1	14.58	85.42
Composite No. 2	16.57	83.43
Composite No. 3	17.23	82.77
Average	16.34	83.66

[a] Samples for trees 3, 5, 9, and 18 were obtained from a second tapping.
Composite 1: Combined resin from the first tapping of trees 1 to 21.
Composite 2: Combined resin from the second tapping of trees 18, 20, and 21.
Composite 3: Combined resin from a second tapping of trees 10, 12, and 16.

According to Wyman [10] the yield of resin from pine trees varies considerably, depending upon such factors as soil, weather, size of trees, species, etc. In general, the quantity of resin obtained from a tree varies directly with the size of the tree and the highest yields are obtained in the hot dry season, which permits of long continuous working.

In Florida, pine-tree resin when distilled yields an estimated average of one barrel of turpentine for three and a third barrels of rosin. Expressed in percentage that would be: 23.09 per cent of turpentine to 76.91 per cent of rosin by volume. According to our results (Table 2), Benguet pine-tree resin gave 16.34 per cent of turpentine to 83.66 per cent of rosin by weight, which would be equivalent to 20.93 per cent of turpentine to 79.07 per cent of rosin by volume. This is about a barrel of turpentine to three and four-fifths barrels of rosin. It would seem that in the Philippines the yield of turpentine from Benguet pine trees is somewhat less than in Florida while the yield of rosin is slightly greater.

In Table 3 are given the constants of Benguet turpentine.

[10] Florida Dept. Agr. Bull. 25 N. S. (1929) 33.

TABLE 3.—*Constants and distillation of Benguet turpentine.*

Sample.[a]	Specific gravity $\frac{30°}{4°}$ C.	Specific rotation $\left(\frac{30° C.}{A\ D}\right)$.	Refractive index $\left(\frac{30° C.}{N\ D}\right)$.	Distillation. °C.				
				Below 155°.	155-157°	157-159°	159-160°	Residue.
				Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Tree No. 3__	0.8475	+30.2	1.4650	3.33	52.0	13.33	12.0	16.44
Tree No. 5__	0.8473	+32.1	1.4644	2.60	45.15	16.50	21.70	14.00
Tree No. 9__	0.8480	+27.05	1.4665	8.8	61.4	7.8	7.6	11.4
Tree No. 18_	0.8488	+32.07	1.4650	10.2	66.0	4.8	4.6	12.4
Composite 1_	0.8483	+29.65	1.4653	0.2	69.6	11.8	5.0	11.2
Composite 2-	0.8495	+28.02	1.4668	3.0	38.4	19.2	9.4	28.0
Composite 3-	0.8630	+22.75	1.4716	1.2	30.4	20.4	18.0	27.4

[a] Samples for trees 3, 5, 9, and 18 were obtained from a second tapping.
Composite 1: Combined resin from the first tapping of trees 1 to 21.
Composite 2: Combined resin from a second tapping of trees 18, 20, and 21.
Composite 3: Combined resin from a second tapping of trees 10, 12, and 16.

Turpentine obtained from the resin of Benguet pine trees is water white in color and has a very pleasant aromatic odor. The data given in Table 3 indicates that Benguet turpentine has a high pinene content (B. P. 155 to 157° C.). It would also appear that samples obtained from different trees seem to vary considerably in composition. This may be due in part to the method of collecting the resin. Some of the samples were exposed to the air longer than others and perhaps suffered a greater degree of oxidation and evaporation.

In Table 4 are given the constants of the pinene fraction (B. P. 155 to 157° C.) of Benguet turpentine. A sample of this fraction was cooled in ice and treated with dry hydrochloric acid gas. The white crystals of pinene hydrochloride thus obtained gave a melting point of 125° to 126° C. Watts gives 125° C. as the melting point of pure pinene hydrochloride.[11]

The authors wish to thank Mr. Arthur F. Fischer, director, Philippine Bureau of Forestry, and Mr. Luis J. Reyes, chief, division of forest products, Bureau of Forestry, for their cooperation and assistance in this work on the chemistry of forest products.

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[11] Dictionary of Chemistry 4 (1927) 663.

TABLE 4.—*Constants of Benguet turpentine (pinene fraction-boiling point 155 to 157° C.).*

Sample.	Specific gravity $\frac{30°}{4°}$ C.	Specific rotation $\left(A\frac{30° C.}{D}\right)$	Refractive index $\left(N\frac{30° C.}{D}\right)$
Tree No. 3	0.8498	+35.03	1.4635
Tree No. 5	0.8558	----------	1.4650
Tree No. 9	0.8480	+30.7	1.4645
Tree No. 18	0.8491	+34.0	1.4637
Composite 1	0.8524	+33.71	1.4640
Composite 2	0.8509	+32.88	1.4641
Composite 3	0.8518	+33.15	1.4638

SUMMARY

We have investigated the turpentine obtained from the resin of Benguet pine trees growing at Baguio in the mountain province of the Philippines.

The yield of pine resin from these trees varies considerably.

The yield of Benguet turpentine is somewhat less than the yield obtained from the resin of Florida pine trees.

Samples of turpentine from the pine resin of different Benguet trees seem to vary considerably in composition.

Benguet turpentine has a high pinene content.

The pinene fraction of Benguet turpentine, obtained from the resin of different pine trees, seems to vary considerably in physical properties.

ILLUSTRATIONS

PLATE 1. Philippine pine trees in Baguio.
2. Tapping a pine tree.

PLATE I. PHILIPPINE PINE TREES IN BAGUIO.

PLATE 2. TAPPING A PINE TREE.

MALARIA TRANSMISSION IN THE PHILIPPINES, I THE NATURAL VECTOR [1]

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ONE PLATE AND ONE TEXT FIGURE

In a preliminary note on malaria transmission,[2] dissection for malarial parasites of about 2,700 anophelines caught in La Mesa and South Portal camps (Novaliches water project), Rizal Province, Luzon, from September to December, 1927, was reported. Table 1 shows the number of each species dissected at the time and the results.

TABLE 1.—*Mosquitoes dissected in 1927.*

Species.	Total mosquitoes.	Stomachs positive.		Salivary glands.	
		Number.	Per cent.	Number.	Per cent.
Anopheles funestus (minimus)	2,283	19	0.83	8	0.35
Anopheles hyrcanus	77	0	.00	0	.00
Anopheles barbirostris	60	0	.00	0	.00
Anopheles rossii	41	0	.00	0	.00
Anopheles karwari	27	0	.00	0	.00
Anopheles tesselatus	5	0	.00	0	.00
Anopheles fuliginosus	194	0	.00	0	.00
Anopheles philippinensis	5	0	.00	0	.00
Anopheles maculatus	1	0	.00	0	.00

The table shows that *Anopheles minimus* Theobald (*A. febrifera* Banks, of Walker and Barber), which we now call *A. funestus*,[3] was the only species found naturally infected. The figures, however, were not satisfactory, 84 per cent being *funestus* while the numbers of the other species examined were small and inconclusive, particularly with regard to *A. ludlowi* Theobald (none). Banks'[4] positive experimental work on *A.*

[1] From the field laboratory, division of malaria control, Philippine Health Service, Tungkong Manga, San Jose del Monte, Bulacan, Luzon.

[2] Manalang, C., Philip. Journ. Sci. 37 (1928) 123.

[3] Manalang, C., Philip. Journ. Sci. 43 (1930) 247.

[4] Philip. Journ. Sci. § B 2 (1907) 513.

ludlowi (salt-water type) in Olongapo, Bataan, should be discarded altogether because he mistook the thoracic ganglion for the salivary gland and the neural nuclei of the thoracic ganglion for sporozoites as he showed them in microphotographs of his mosquito sections.[5] In his mosquito survey of Cervantes,[6] Ilocos Sur, an inland mountainous district, he also incriminated the fresh-water *ludlowi* on the strength of his findings in Olongapo. Walker and Barber[7] infected experimentally *A. febrifera* Banks (*minimus*) and *A. maculatus* Theobald. Tiedeman[8] and Mieldazis[9] suspected *ludlowi* (fresh water) and *funestus* (*minimus*) as vectors, supposedly on epidemiological evidence. What influence the work of Banks, Walker, and Barber had on their conclusion is not known. The only Philippine record of mosquito dissections for natural malarial infection was made by one of them (Tiedeman) on 360 negative *A. subpictus* Grassi, but none on their incriminated species. Only one *A. maculatus* Theobald, an important carrier in Malaya, was dissected in 1927.

Mosquito catches were carried on during the past two years in eight different camps on the water-project line, San Francisco del Monte and Novaliches, two "barrios," distant and unconnected with the project (see fig. 1). San Francisco del Monte is a prolific fresh-water *ludlowi* district. Table 2 shows blood surveys in the different places observed. In San Francisco del Monte, almost all of the *funestus* were caught in the human-baited trap operated from September, 1928, while the other species were caught on cows or water buffaloes. In South Portal, the trap has been used exclusively since March, 1928 (Plate 1, fig. 1). The trap is a small, wire-screened house, 2.5 by 2.5 by 2.5 meters, provided with a wire-screen ceiling and four doors. The catcher, with flashlight, catches between 7 and 10 p. m. He sleeps in the trap under a mosquito net. The doors are closed at 4 a. m., and he catches the trapped mosquitoes in the morning. In North Portal, a portable trap (Plate 1, fig. 2) has been used since September, 1928, while in Tungkong Manga, another portable trap (Plate 1, fig. 3) has been in use since June, 1929, and three traps attached to the field laboratory have been used since September of the same year. In the other stations mosquitoes were caught outside the houses and on animals.

[5] Manalang, C., Philip. Journ. Sci. 37 (1928) 123.
[6] Banks, Philip. Journ. Sci. § B 3 (1908) 335.
[7] Philip. Journ. Sci. § B 9 (1914) 381; § B 10 (1915) 177.
[8] Journ. Prev. Med. 3 (1927).
[9] Ann. Report Philip. Health Service (1925).

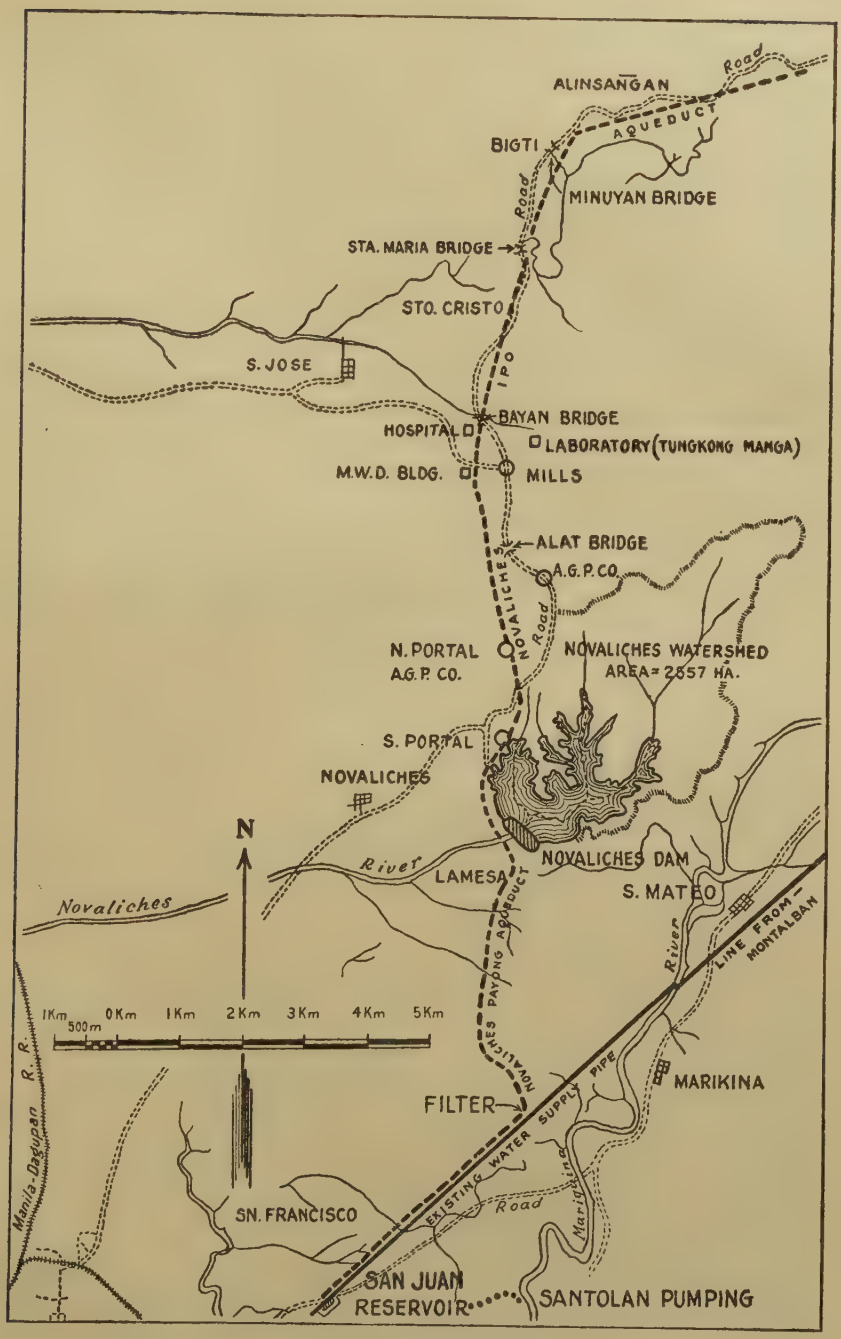

FIG. 1. The Novaliches water project.

They were caught regularly and brought to Manila daily except on Sundays and holidays. The dead mosquitoes were dissected at once, and those living were transferred into wide-mouthed bottles stoppered with a pledget of cotton saturated with water or dilute glucose water and kept in an ice box at automatically regulated temperature between 23 and 25° C. This treatment was found necessary to keep engorged mosquitoes alive long enough for positive blood meals to develop into oöcysts. Beginning September 1, 1929, all the mosquitoes were examined in the field laboratory at Tungkong Manga. Methods used for preserving malarial specimens taken from the mosquito have already been published [10] with microphotographs. Photographic proofs of natural malaria infection in any species is believed very essential not only for future reference but in order that it may save useless and costly attempts at mosquito control. Fear of *ludlowi* and attempts against this species in Davao fishponds on the strength of Banks' findings and supported by the incriminations of later investigators form an excellent example. Tables 3 and 4 show the dissections in 1928 and 1929, respectively.

COMMENTS

1. Tables 1 and 2 show that each species was numerically well represented.

2. Positive mosquitoes (*funestus*) were found in five of seven places in 1928 and in three of seven places in 1929.

3. All the positives were found in *A. funestus* excepting one heavily infected stomach of *A. vagus* Donitz from San Francisco del Monte, in June, 1929. In fifteen *funestus* both stomach and salivary glands were infected.

4. La Mesa supplied 429 *funestus* in a total catch of 521 in 1928 with 14 positives. South Portal for 1928 and 1929 supplied 7,025 *funestus* in a total catch of 7,505 with 210 positives. The prevalence of *funestus* in both these stations (over 92 per cent) showed them to be typically *funestus* districts.[11]

5. In San Francisco del Monte the *funestus* catch was about 4 per cent of the total (594 of 14,157) with 2 positives, while in Tungkong Manga and North Portal, they constituted 29 and 30 per cent, respectively, of the total catches with 7 positives in the former and 25 positives in the latter.

6. A total of 7,036 *ludlowi* from San Francisco del Monte (the *ludlowi* district) in a total catch of 14,011; 2,146 from

[10] Manalang, C., Philip. Journ. Sci. 42 (1930) 481.

[11] Even after differentiation of *aconitus* var. *filipinæ*.

TABLE 2.—*Blood surveys in the different places observed.*

Place.	Surveys.		Number examined.	Types of infection.				Positive.	
	Number.	Date.		*P. vivax.*	*P. malariæ.*	*P. falciparum.*	Mixed.	Total.	Per cent.
1. La Mesa	1	Dec., 1926	332	3	0	5	0	8	2.41
Do	2	Feb., 1927	80	8	0	9	1	18	22.50
Do	3	----- 1927	45	18	0	5	1	24	[a] 53.33
Do	4	June, 1928	300	5	0	12	0	17	5.67
Do	5	Apr., 1930	28	1	0	0	0	1	3.40
2. South Portal	1	Sept., 1928	40	1	0	2	0	3	7.50
Do	2	Sept., 1929	91	11	0	7	0	18	19.78
Do	3	Apr., 1930	130	1	0	0	0	1	0.70
3. North Portal	1	June, 1928	43	5	0	2	0	7	16.27
Do	2	Sept., 1928	49	11	0	4	0	15	30.61
Do	3	Jan., 1929	86	4	0	3	1	8	9.30
4. Atlantic, Gulf, and Pacific Co	1	June, 1928	130	13	0	9	4	26	20.00
5. Tungkong Manga	1	Jan., 1927	56	0	0	0	0	0	.00
Do	2	Aug., 1929	73	18	0	8	0	26	35.60
6. San Francisco del Monte	1	Dec., 1927	23	6	0	1	0	7	[b] 30.40
Do	2	Feb., 1928	78	12	0	2	0	14	[b] 18.00
7. Novaliches	1	----- 1927	182	3	0	6	0	9	[c] 4.94
Do	2	Dec., 1928	108	3	1	2	0	6	[b] 5.50
8. Bigti (including Minuyan)	1	Oct., 1929	200	10	0	2	1	13	6.50
Bigti	2	Nov., 1929	51	1	0	0	0	1	1.96
9. Santo Cristo	1	Jan., 1927	180	0	0	1	0	1	0.60
Do	2	Oct., 1929	59	10	0	0	2	12	20.34
10. Alinsangan									

[a] Children, splenomegaly 84.44 per cent.

[b] Children.

[c] Children, splenomegaly 8.24 per cent.

TABLE 3.—*Mosquitoes dissected in 1928.*

Place.	*A. funestus (minimus).*				*A. tesselatus.*	*A. hyrcanus (sinensis).*	*A. barbirostris.*	*A. rossii.*[a]	*A. karwari.*	*A. philippinensis.*	*A. fuliginosus.*	*A. ludlowi.*	*A. kochi.*	*A. maculatus.*	Total.
	Total.	Positive.													
		Stomachs.	Salivary glands.	Per cent.											
South Portal	5,765	107	83	3.31	10	6	83	66	18	40	8	9	-------	4	6,010
San Francisco	297	2	-------	.67	55	331	171	2,390	51	1,218	155	2,520	49	7	7,244
North Portal	2,171	17	4	.79	898	1,749	259	835	397	922	538	178	112	23	8,082
La Mesa	429	7	7	3.26	-------	-------	12	22	1	22	32	2	-------	1	521
Novaliches	585	-------	-------	-------	1	-------	71	846	1	8	18	19	15	3	1,567
Atlantic, Gulf, and Pacific Co	359	10	3	3.60	-------	-------	-------	1	-------	-------	-------	-------	-------	-------	360
Tungkong Manga	273	-------	-------	-------	14	5	6	22	4	2	4	28	6	1	365
Total	9,879	143	97	2.50	978	2,091	602	4,182	472	2,212	755	2,756	182	39	24,149

[a] *Anopheles vagus*, mostly; *subpictus*, few.

TABLE 4.—*Mosquitoes dissected in 1929.*

Place.	*A. funestus (minimus).*				*A. aco.*[a]	*A. tessellatus.*	*A. stinensis.*	*A. barbirostris.*	*A. rossii.*[b]	*A. karwari.*	*A. philippinensis.*	*A. fuliginosus.*	*A. ludlowi.*	*A. kochi.*	*A. maculatus.*	Total dissected.
	Total.	Positive stomachs.	Positive salivary glands.	Per cent infection.												
South Portal	1,260	12	8	1.6	------	6	37	13	69	4	67	9	8	------	23	1,496
San Francisco	297	0	0	0	------	7	79	61	1,863	10	8	20	4,516	7	45	6,913
North Portal	3,020	2	2	0.13	------	474	644	327	2,466	137	61	189	979	75	358	8,730
Bigti	191	0	0	0	1	9	345	66	755	3	38	13	10	48	6	1,485
Tungkong Manga	4,762	4	3	0.14	4	142	689	534	5,937	154	849	249	2,118	356	1,346	17,140
Santo Cristo	266	0	0	0	19	44	285	84	2,360	25	418	210	893	86	191	4,881
Alinsangan	41	0	0	0	------	2	23	9	178	2	4	------	------	10	------	269
Total	9,837	18	13	------	24	684	2,102	1,094	13,628	335	1,445	690	8,524	582	1,969	40,914

[a] Separate identification from *funestus* toward the end of the year.
[b] *Anopheles vagus* + *subpictus*, one positive stomach in June (San Francisco).

Tungkong Manga in a total of 17,140; 1,157 from North Portal in a total catch of 16,812, or 10,339 *ludlowi* from three places, were all found negative. Altogether 11,280 *ludlowi* were dissected during 1928 and 1929.[12] Of 594 *funestus* from San Francisco del Monte, 5,035 from Tungkong Manga, and 5,191 from North Portal, or a total of 10,820 *funestus* (about the same as the number of *ludlowi* from these places), 34 positives were found. Surveys of coastal places where brackish-water *ludlowi* is abundant have so far revealed no indigenous malaria. Coastal towns may have malaria, but they are invariably at the foot of hills or mountains, suitable for *funestus* breeding.

7. In 1929, Tungkong Manga and North Portal supplied 1,346 and 358 *A. maculatus,* respectively. Altogether 2,008 negative *maculatus* [13] were dissected from different places, in five of which *funestus* was found infected.

CONCLUSIONS

Two years of dissection of anophelines caught in ten places shows conclusively that of the twelve species numerically well represented in about 65,000 mosquitoes *A. funestus* (*minimus*), the same vector found in 1927, is the natural vector of malaria in the Philippines.

It may still be possible to demonstrate that under natural conditions other anopheline species may transmit malaria, but the topography and mosquito fauna of the places studied are so typical of the many known malarious regions that such would be exceptional.[15]

[12] Dissections in 1930, January to July, 2,485.

[13] Dissections of 1930, January to July, 962.

[15] Of the anopheline mosquitoes captured in a portable trap (large mosquito net) set in a room with several known malaria cases at the Ipo Gold Mine camp, Bulacan, during the first three months of 1931, three with öocysts in the stomach and one with sporozoites in the glands were found among eighty-seven *A. funestus;* among thirty-eight *A. maculatus,* two had öocysts only in the stomach and one had both this organ and the glands infected. All blood-engorged mosquitoes were kept for several days until death in a humid chamber.

ILLUSTRATIONS

PLATE 1

FIG. 1. Mosquito trap at South Portal.
2. Portable trap at North Portal.
3. Another type of portable trap, at Tungkong Manga.

TEXT FIGURE

FIG. 1. Map of the Novaliches water project. 249

1

2

3

PLATE 1.

THE ETHER-INSOLUBLE LEAD SALT OF LUMBANG OIL [1]

By D. M. Birosel

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Several investigations [2] have been reported on lumbang oil. The oil has been found to consist mainly of the glycerides of oleic, linolic, and linolenic acids. The glycerides of certain solid acids are present in a small extent. Oxyacids have been detected that presumably are not original in the oil but have been formed by the action of atmospheric oxygen on the glycerides of unsaturated acids. The solid acids of lumbang oil and the oxyacid bodies formed in the oil have not been studied, though their presence has been mentioned in previous works.

Though several papers have been reported on lumbang oil, it is significant to note that there has been no attempt to identify the solid constituent of the oil. It seemed interesting to study the ether-insoluble lead salt of lumbang oil as it might lead to the discovery of new solid acids or solid acids already known. It is the purpose of this article to present the data and observations obtained in this study and to discuss their significance in the identification of a solid acid found in lumbang oil.

EXPERIMENTAL

Material used.—The lumbang (candlenut) oil used in this investigation was the remainder of the material which the writer used in his unsuccessful work on the preparation of α-bromlinolic acid tetrabromide.

[1] Contribution from the research laboratory chemistry department, University of the Philippines. This work was begun in the organic laboratory of the Bureau of Science.

[2] Aguilar, R. H., Philip. Journ. Sci. § A 12 (1917) 235; 14 (1919) 275; Brill and Agcaoili, Philip. Journ. Sci. § A 10 (1915) 111; Richmond and del Rosario, Philip. Journ. Sci. § A 2 (1907) 439; Welcot and Thompson, Press Bull. Hawaii Agr. Exp. Station 39 (1913); West and Montes, Philip. Journ. Sci. 18 (1921); West and Gonzaga, Philip. Journ. Sci. 23 (1923) 277; West and de Leon, Philip. Journ. Sci. 24 (1924) 123; West and Smith, Philip. Journ. Sci. 32 (1927) 297; West and Santiago, Philip. Journ. Sci. 32 (1927) 41; West and Cruz, Philip. Journ. Sci. 42 (1930) 251.

To eliminate the possible influence of oxyacids upon the observations recorded in this paper, the following experiments were undertaken.

Oxyacids are insoluble in petroleum ether while the solid acids and unsaturated acids are soluble in this solvent. It is, therefore, not difficult to test the presence of oxyacids in the solid acid constituent of lumbang oil. A known amount of the solid acids was dissolved in petroleum ether. No portion remained undissolved. It was passed through a filter paper into a tared small beaker. There was no residue left in the paper. The solvent was evaporated and the residue was put to dry for an hour in an electric oven maintained at 100° C. The starting amount was recovered. Thus it is shown that no oxyacids contaminated the solid acids used in this work.

It is interesting to note that the oxyacids were characterized by West,[3] as precipitating from petroleum ether solution. Starting with 100 grams of oil the writer passed air through it at such a rate that the oil was kept stirred. The oil was hydrolyzed and the free acid was extracted with ether and dried. The solvent was evaporated and the dried free acids were dissolved in petroleum ether. The solution was set aside to clear up. Drops of brown colored oil were found to have separated and stuck to the wall of the flask. The clear solution was decanted and the drops of brown oil were washed with the same solvent. This brown oil is undoubtedly the same substance which West characterized as precipitating from petroleum ether solution. The amount of oxyacids obtained from 100 grams of lumbang oil blown with air for thirty-six hours did not exceed 0.4 per cent. These oxyacid bodies were found to dissolve in alcohol and ether. Dilute alkali solution reacted with them. The lead salts of these oxyacids are brown in color and do not melt even at the maximum temperature reached by the sulphuric acid bath. The free oxyacids are reddish brown in color which is believed by the writer to give rise to the color of the oil containing unsaturated glycerides. The oxyacids, when freed of solvent molecules, assume a resinlike mass but do not become solid after an exposure of several days.

From the above observations it appears that the starting material of this work did not contain oxyacid bodies to the extent of 0.4 per cent. The absence of oxyacids in the solid acids has been shown. It appears that they were eliminated in the course of purification of the lead salts and of the free solid acids.

[3] Philip. Journ. Sci. 42 (1930) 252.

Preparation of the ether-insoluble lead salt of lumbang oil.— In this work the procedure [4] adopted to prepare this compound is identical with the method usually followed by oil investigators in separating the solid acid constituents of an oil from its unsaturated acids.

Five hundred cubic centimeters of lumbang oil was treated with 100 grams of potassium hydroxide dissolved first in 50 cubic centimeters of water to facilitate its solution with 500 cubic centimeters of aldehyde-free alcohol. The solution was digested on the steam bath for six hours, in a 2-liter round-bottomed flask fitted with a Liebig condenser. After digestion the solution was made neutral with acetic acid. The greater portion of the alcohol was then distilled off. In the meantime a hot solution of the required amount of lead acetate was made up and filtered. The hot lead acetate solution was added to the hot potassium salt of lumbang oil, shaking the reaction flask continuously while adding. More hot water was added. It was allowed to cool and the aqueous solution was decanted. The sticky lead salt was again washed with hot water and cooled before pouring off the aqueous solution. The washing was freed of water as much as possible. Ether was added to it and warmed gently on the water bath. This dissolved the salts of the unsaturated acids. The flask was set aside in a refrigerator over night, and the next morning it was filtered by gentle suction to separate the ether-insoluble lead salt. The product of first filtration, which was rather sticky, was again treated with ether. It was cooled and filtered. The lead salt was washed further with ether.

One gram of the above ether-insoluble lead salt was digested with ether and cooled. This was repeated until it was white and lost all its stickiness. It was dried in a calcium chloride desiccator for two days. It was found to melt at 104.5° to 105.5°.[5] The salt was analyzed for lead as sulphate.

Analysis:

	Found Pb. Per cent.
0.1515 gram salt gave 0.0210 gram of dry $PbSO_4$	27.87
0.0526 gram salt gave 0.0214 gram of dry $PbSO_4$	27.79

[4] Gusserow, Liebig's Ann. 27 (1928) 153; Varentrapp, Liebig's Ann. 35 (1840) 197; Baughman and Jamieson, Journ. Am. Chem. Soc. 42 (1920) 152.

[5] Gerard, Ann. 27 (1892) 560, prepared the lead salt of daturic acid and reported the compound as melting at 104° to 105° and to be slightly soluble in hot alcohol.

Free solid acid and fractional crystallization of its barium salt.—The rest of the ether-insoluble lead salt obtained above was digested with excess dilute hydrochloric acid solution for an hour on the steam bath. An oil separated that solidified when the contents of the flask were cooled. The solid was extracted with ether and the ether solution was passed through a filter. The solvent was evaporated. The residue was found to melt at 54.5° to 55.5°. It was crystallized from alcohol; short white needle crystals were obtained that were found to melt at 57.5°.[6]

About 3 grams of the crystallized substance was made into its barium salt and fractionally crystallized according to the procedure adopted by Gerard. The first crop of crystals was crystallized twice from alcohol and then hydrolyzed with dilute hydrochloric acid to obtain the free acid. After crystallizing from alcohol, short needle crystals melting at 57.5°, as formerly observed, were obtained.

The neutralization equivalent of the free solid acid was determined. With 0.2 gram of the acid dissolved in neutral aldehyde free alcohol 7.4 cubic centimeters of 0.1 *N* sodium hydroxide (F = 1.0017), using phenolphthalein as an indicator, was used. The neutralization equivalent calculated from the experimental data is 269.81.[7]

Three months later, another determination was taken; 0.2 gram of the acid, dissolved in neutral alcohol, used 6.50 cubic centimeters of 0.1 *N* sodium hydroxide (F = 1.1377), giving a

[6] Gerard, Ann. 26 (1892) 555, isolated daturic acid from the oil of the seeds of *Datura stramonium* and reported it as crystallizing into white needle crystals that melt at 55°. Kreis and Hafner, Ber. 36 (1903) 2770, isolated daturic acid from the fat of the hog and found it to melt at 55° to 56°. Holde and Stange, Ber. 34 (1901) 2402, 38 (1905) 1245, isolated daturic acid from olive oil and found it to melt at 54° to 57°. Nordlinger, Ber. 25 (1892) 578, reported 57° as the melting point of an acid that he claimed identical with Gerard's daturic acid. Meyer and Klimont, M. 36 (1915) 28, obtained daturic acid, melting point 56.5° to 57.5°, from horse fat. Meyer and Eckert, M 31 (1910) 1227, obtained daturic acid from the oil of coffee beans and reported the acid as melting at 57°. Meyer, Klimont, and Meisl, M 35 (1914) 1115, obtained heptadecylic acid from horse fat and reported it as melting at 57° to 57.5°. Meyer and Beer, M 33 (1912) 311, repeated the work of Gerard on the oil of the seeds of *Datura stramonium*. They reported daturic acid as melting at 59° to 59.5° and proved it identical with margaric acid. This work proved beyond doubt that daturic acid is a true acid.

[7] The neutralization equivalent of daturic acid, as given in Mullikan's Identification of Pure Organic Compounds 1: 54, is 270.

neutralization value of 270.45, which agrees very closely with the first figure. Using the mean as the molecular weight of the free acid, the calculated per cent of lead in the salt is 27.79, which agrees very closely with the analytical figures given above. The fatty acid that gives the above molecular weight is heptadecylic acid.

Analysis: [8]

	Found C. Per cent.
5.313 mg. Subst. gave 14.730 mg. CO_2 and 5.964 mg. H_2O.	75.61
	Found H. Per cent.
Calculated for $C_{17}H_{34}O_2$: C, 75.6 per cent; H, 12.6 per cent.	12.56

Molecular-weight determination by the Rast method.—Depression observed in the melting point of camphor by dissolving 3.87 milligrams of the solid acid in 24.504 milligrams camphor was 23°. A micro balance was used in weighing substances. The molecular weight calculated from these data is 275.1. Another experiment using the ordinary analytical balance was made. Observed depression in the melting point of camphor by dissolving 7.9 milligrams of the free acid in 69.5 milligrams of camphor was 16.5°. The molecular weight obtained from these results was 276.6. The figures are quite close and are comparable with the figure obtained for the neutralization equivalent of the acid.

To show the identity of the solid obtained from lumbang oil, several salts were prepared.

Lithium salt.—One gram of the free acid was treated with an alcoholic solution of the equivalent amount of lithium acetate prepared from lithium carbonate and acetic acid. The acid salt was precipitated from the hot alcoholic solution. It was filtered by suction and washed with hot 95 per cent alcohol. The dried salt melted at 220°.

Analysis:

	Found Li. Per cent.
0.1 gram salt gave 0.0195 gram dry Li_2SO_4	2.46
Calculated for $LiC_{16}H_{33}CO_2$	2.51

Sodium salt.[9]—One gram of the free solid acid dissolved in alcohol was treated with an alcoholic solution of the equivalent

[8] The writer is kindly indebted to Prof. A. Santos, School of Pharmacy, University of the Philippines, for this micro-analysis.

[9] Gerard, Ann. 27 (1892) 557, prepared the sodium acid salt and the neutral salt. He reported the neutral salt coming down from the solution as a gelatinous mass and that crystallization was difficult. The acid salt was found by analysis to contain one portion of sodium to two of the acid.

amount of sodium hydroxide. The salt did not precipitate from the hot alcoholic solution. When it was cooled rapidly the whole solution gelatinized. When cooled gently the salt deposited as a white precipitate. It was filtered by suction and washed with dilute alcohol. The dried salt was found to soften at 105°, became opaque liquid at 115°, and was transparent at 220°.

Analysis:

	Found Na. Per cent.
0.2 gram salt gave 0.0255 gram dry Na_2SO_4	4.13
Calculated for $NaO_2C_{17}H_{33}.C_{17}H_{34}O_2$	4.096

Potassium salt.[10]—This compound was prepared in the same way as the sodium salt and behaved like it. It is soluble in hot ethyl alcohol. It gelatinizes when its alcoholic solution is rapidly cooled. When cooled slowly, it comes down as a white precipitate. The dry salt softens at 110°; becomes an opaque liquid at 135°, and becomes a clear liquid at 138°.

Analysis:

	Found K. Per cent.
0.2 gram of salt gave 0.300 gram of dry K_2SO_4	6.75
Calculated for $KO_2C_{17}H_{33}.C_{17}H_{34}O_2$	6.77

Rubidium salt.—This salt was prepared similarly to the above salts by treating 1 gram of the free solid acid dissolved in alcohol with the equivalent amount of rubidium acetate dissolved in the same solvent. Rubidium acetate was prepared in the laboratory by the interaction of rubidium bromide and silver acetate prepared from the action of acetic acid upon silver carbonate, which was obtained by the action of sodium carbonate upon silver nitrate solution. The rubidium salt was precipitated as a white solid when its alcoholic solution was gently cooled. The precipitate was filtered by suction and washed several times with 95 per cent alcohol. The dry salt was found to melt sharply at 120°.

Analysis:

	Found Rb. Per cent.
0.1 gram salt gave 0.0215 gram of dry Rb_2SO_4	13.76
Calculated for $RbO_2C_{17}H_{33}.C_{17}H_{34}O_2$	13.67

[10] Gerard, Ann. 27 (1892) 556, prepared the potassium salt and he reported having obtained a neutral salt and an acid salt. The neutral salt of potassium behaves like the neutral salt of sodium. By analysis, the potassium acid salt is made up of one portion of the metal to two of the acid.

Zinc salt.[11]—One gram of the potassium salt of the acid as prepared above was dissolved in warm alcohol and this was treated with the equivalent amount of zinc chloride dissolved in the same solvent. This zinc salt of the acid precipitated from the hot alcoholic solution. It was filtered by suction and washed with warm 95 per cent alcohol. The salt was dried at 100°.

Analysis:

	Found Zn. Per cent.
0.1 gram of salt gave 0.0262 gram of dry $ZnSO_4$	10.61
Calculated for $Zn(C_{17}H_{33}O_2)_2$	10.82

Calcium salt.—This compound was prepared similarly to the zinc salt of the acid. A white precipitate came down from the hot alcoholic solution of the reactants. It was filtered by suction and washed with hot 95 per cent alcohol. The salt was dried at 100°. It was found to melt at 182° to 183°.

Analysis:

	Found Ca. Per cent.
0.1 gram of salt gave 0.0220 gram of dry $CaSO_4$	6.50
Calculated for $Ca(C_{17}H_{33}O_2)_2$	6.93

Mercuric salt.—This compound was prepared in the same way as were the salts of the bivalent metals recorded above. The salt crystallized into short needle crystals from alcohol. It was filtered by suction and washed well with 95 per cent alcohol. The dry crystals were found to melt at 113° and solidified completely at 110°. Because the sulphate of mercury volatilizes, the free acid was determined from a weighed amount of the salt.

Analysis:

	Found $FC_{17}H_{34}O_2$. Per cent.
0.2045 gram of salt gave 0.1491 gram of dry acid	72.91
	Found $C_{17}H_{33}O_2$. Per cent.
Calculated for $Hg(C_{17}H_{33}O_2)_2$	73.13

Strontium salt.—One gram of the free acid was treated with an equivalent amount of strontium acetate prepared from strontium carbonate and acetic acid, using alcohol as a reaction medium. The salt precipitated as a white solid from the hot alcoholic solution. It was filtered by suction and washed well with hot alcohol. The dry compound was found to melt above 265°.

[11] Gerard, Ann. 27 (1892) 559, reported having prepared the zinc salt of daturic acid.

Analysis:

	Found Sr. Per cent.
0.1 gram of salt gave 0.0261 gram of dry $SrSO_4$	12.45
Calculated for $Sr(C_{17}H_{33}O_2)_2.4H_2O$	12.55

Thallium salt.—This compound was prepared in the same way as the above strontium salt. The salt did not precipitate from hot alcoholic solution, but when it was cooled by running water a white solid came down. The precipitate was filtered, washed, and dried at 100°.

Analysis:

	Found Tl. Per cent.
0.1 gram of salt gave 0.0460 gram of dry Tl_2SO_4	37.21
Calculated for $C_{17}H_{33}O_2Tl.4H_2O$	37.41

Uranyl salt.—One gram of the free acid was dissolved in warm alcohol, and this was treated with a hot alcoholic solution of the equivalent amount of uranyl acetate. A yellowish solid precipitated. It was dried at 100 °. It was found to soften at 146° and to melt at 150°.

Analysis:

	Found UO_2. Per cent.
0.1 gram of salt gave 0.0415 gram of dry UO_2SO_4	30.62
Calculated for $UO_2(C_{17}H_{33}O_2)_2.4H_2O$	30.68

Cadmium salt.—This compound was prepared in the same way as the strontium salt. It was precipitated from hot alcohol. The solid was filtered and washed with hot alcohol. The dry salt was found to melt at 104.5° to 105.5°.

Analysis:

	Found Cd. Per cent.	Found $4H_2O$ Cd. Per cent.
0.1 gram of salt gave 0.0283 gram of dry $CdSO_4$	15.12	
Calculated for $Cd(C_{17}H_{33}O_2)_2$		15.54

Barium salt.[12]—This salt was prepared like the preceding compound. A white fine powder was obtained after drying.

Analysis:

	Found Ba. Per cent.
0.1 gram of salt gave 0.0342 gram of dry $BaSO_4$	20.02
Calculated for $Ba(C_{17}H_{33}O_2)_2$	20.32

[12] Gerard, Ann. 27 (1892) 559, prepared the barium salt of daturic acid.

Methyl ester.—About 7 grams of the free acid was melted and to it was added the calculated amount of phosphorus trichloride ($\frac{1}{3}$m). The mixture was digested very gently with a small flame. A yellowish sticky solid adhered to the wall of the flask, which was fitted with a ground-glass condenser. In about an hour the reaction was complete, and the liquid product was set aside to cool. It solidified in the flask. It was found to soften at 52° and completely liquefied at 60°.

About 2 grams of the acid chloride was treated with an excess of methyl alcohol. The solution was put in a warm place for one hour after which the liquid methyl ester that separated from the methyl alcohol was separated. Ether was added and the solution was washed with dilute sodium hydroxide and with distilled water. The ether solution was dried with sodium carbonate and filtered. The solvent was evaporated and a liquid residue was obtained that solidified when cooled with running water. The solid was found to melt at 30°[13] in a small capillary tube. It solidified completely at 28°, giving fine needle crystals.

For an hour 0.2055 gram of the ester was digested with an excess of alcoholic potash. The soap solution was treated with excess dilute hydrochloric acid solution and was digested for half an hour. The flask and its contents were cooled and the acid was extracted with ether and transferred to a small tared flask. The solvent was evaporated, and the residue was put in a 100° oven for an hour to dry. The residue was found to weigh 0.1954 gram.

Analysis:

	Found $C_{17}H_{34}O_2$. Per cent.
0.2055 gram of ester gave 0.1954 gram of dry acid	95.05
	Found $C_{16}H_{33}COOH$. Per cent.
Calculated for $C_{16}H_{33}CO_2CH_3$	95.06

The free acid obtained from the ester melted sharply at 57.5°.

Ketone from the solid acid.—Approximately 1 gram of the acid was distilled with about 0.2 gram of dry calcium oxide. The distilled compound was extracted with ether and washed with dilute sodium hydroxide and distilled water. The solvent was evaporated, and the residue was crystallized from alcohol.

[13] Gerard, Ann. 27 (1892) 562, prepared the methyl ester of daturic acid and reported it as crystallizing into needles which melted at 30° and solidified at 28°. Meyer and Eckert, M, 31 (1910) 1227, prepared the methyl ester and reported it as melting at 30°.

Pearly scales were obtained which melted at 78° and crystallized at 75° to 76°.[14] It is insoluble in water and cold alcohol but very soluble in hot alcohol and ether.

Determination of the solid acid constituent of lumbang oil.—The procedure adopted in determining the solid acid constituent of the oil is the same as the method used in preparing the ether insoluble lead salt described elsewhere in this paper with a more careful manipulation of the different steps so that the compounds were not unduly exposed to the oxidizing effect of the air. Before filtering the ether-insoluble lead salt, the ether solution was sufficiently cooled. The washing of the lead salt with previously cooled ether was carried out more thoroughly so that the salt obtained was perfectly white and had lost all its stickiness. That a pure salt was obtained was shown by the fact that the free solid acid obtained in two determinations melted sharply at 57.5 ° without any depression in melting point when mixed with the recrystallized acid obtained above. The free acid obtained in two experiments was dried for one hour at 100° before the final weight was taken.

Analysis:

	Found $C_{16}H_{33}CO_2H$. Per cent.
50 grams of lumbang oil gave 1.8935 grams of dry white acid	3.78
10 grams of lumbang oil gave 0.379 gram of dry white solid acid	3.79

The figures obtained in two determinations agree very closely. The content of solid acid in lumbang oil as found in this work is, therefore, 3.79 per cent.[15]

DISCUSSION

The analytical data obtained from the salts of the solid acid of lumbang oil showed that the substance is a heptadecylic acid. It was further pointed out that the acid has only one replaceable

[14] Gerard, Ann. 27 (1892) 563, prepared a ketone from daturic acid by distilling the acid with dry calcium oxide. He reported it as crystallizing into shiny scales which melted at 75.5° to 76°.

[15] In one of the researches reported by West, Philip. Journ. Sci. 18 (1921) 619, he mentioned solid acids being present in the oil to the extent of 2.68 per cent. He stated that this mixture of solid acids melted at 54° and that it had an iodine number of 18.05 (Hubl). In a recent paper by West and Cruz, Philip. Journ. Sci. 42 (1930) 251–57, the authors reported a lower percentage of the amount of solid acids which is only 2.02 per cent. They did not identify their solid acids.

hydrogen atom. The molecular weight obtained from the measurement of the neutralization equivalent is identical with the molecular weight of heptadecylic acid.

This heptadecylic acid shows properties identical with those of daturic acid. The methyl ester and ketone obtained from this acid show properties identical with the properties of the corresponding derivatives of daturic acid. The salts prepared in this work show properties identical with the properties of the salts of daturic acid which have been already reported in the chemical literature. It appears, therefore, that the heptadecylic acid isolated from the solid constituent of lumbang oil is daturic acid.

It has been stated elsewhere that this heptadecylic acid was obtained by fractional crystallization of its barium salt. Gerard has shown in his work that this is a practicable method and the experience obtained from this work supports this claim.

Comparing the salts of the monovalent alkali metals, a striking difference is noted. The lithium salt was precipitated from warm alcoholic solution, like the salts of the bivalent alkaline earth metals, while the salt of sodium, potassium, and rubidium were precipitated from cold alcoholic solution. Lithium was found to give only the neutral salt, while sodium, potassium, and rubidium gave both the acid and neutral salts. The neutral salts of sodium, potassium, and rubidium were observed to gelatinize. A small amount of these salts is sufficient to gelatinize a thousand times its own weight of alcohol.

The salts of the alkaline earth metals behave alike except that the strontium and cadmium salts have four molecules of combined water as calculated from analysis. The salt of thallium, like that of cadmium and strontium, shows four molecules of combined water; the uranyl salt also contains four molecules of combined water.

Two determinations of the amount of solid acids in lumbang oil gave 3.79 per cent. The acids obtained in these determinations were perfectly white, which shows the absence of deep brown red oxyacids. They were found to melt sharply at 57.5°, which indicates that pure substances had been prepared.

SUMMARY

The ether-insoluble lead salt obtained from lumbang oil was found to be the salt of heptadecylic acid. The heptadecylic acid obtained from the lead salt appears to be identical with daturic acid.

NEW OR LITTLE-KNOWN TIPULIDÆ FROM THE PHILIPPINES (DIPTERA), VIII *

By CHARLES P. ALEXANDER

Of Amherst, Massachusetts

THREE PLATES

All species of crane flies discussed in the present paper are from central and northern Luzon, where they were collected in Mountain and Rizal Provinces, by Duyag; in Laguna Province, by McGregor; and in Cagayan, Mountain, and Pampanga Provinces, by Rivera. As before, I am greatly indebted to Mr. McGregor and his coworkers for their continued interest in collecting and saving these fragile flies from many parts of the Philippines. I am again indebted to Mr. McGregor for the privilege of retaining the material herein considered.

Our knowledge of the Philippine crane flies is now such that it seems advisable to give a list of the generic and subgeneric groups so far discovered in the Islands. All of the groups listed below have been taken in Luzon, where especial attention has been devoted to the Tipulidæ. Names marked with an asterisk (*) indicate groups that have been taken in Luzon but not in Formosa. Groups marked with an obelisk (†) have not been recorded hitherto from the Philippines.

Generic and subgeneric groups of Tipulidæ known to occur in the Philippine Islands.

Tipulinæ.
- Tipulini.
  - *Pselliophora* O. S.
  - *Ctenacroscelis* End.
  - *Tipula.*
    - *Tipula* Linn.
    - *Acutipula* Alex.
    - *Nephrotoma* Meig.
    - *Tipulodina* End.
  - * *Macgregoromyia* Alex.
  - * *Scamboneura* O. S.
  - *Dolichopeza.*
    - *Nesopeza* Alex.
  - * *Megistocera* Wied.

* Contribution from the Entomological Laboratory, Massachusetts Agricultural College.

Cylindrotominæ.
* *Stibadocera* Brun.
Limoniinæ.
Limoniini.
Limonia.
Limonia Meig.
Libnotes Westw.
† *Discobola* O. S.
Dicranomyia Steph.
Geranomyia Hal.
† *Rhipidia* Meig.
*† *Doaneomyia* Alex.
Thrypticomyia Skuse.
Pseudoglochina Alex.
Goniodineura v. d. W.
Alexandriaria Garr.
Euglochina Alex.
Helius.
Helius St. Farg.
Eurhamphidia Alex.
Antocha.
* *Orimargula* Mik.
Orimarga O. S.
Lechriini.
* *Lechria* Skuse.
Hexatomini.
Epiphragma O. S.
Pseudolimnophila Alex.
† *Pilaria* Sint.
Limnophila.
Limnophila Macq.
† *Ephelia* Schin.
† *Dicranophragma* O. S.
† *Adelphomyia* Bergr.
Eriocera Macq.
Elephantomyia.
Elephantomyodes Alex.
Eriopterini.
Conosia v. d. W.
Trentepohlia.
* *Paramongoma* Brun.
Mongoma Westw.
Trentepohlia Big.
Toxorhina.
Ceratocheilus Wesché.
Toxorhina Lw.
Gonomyia.
Ptilostena Bergr.
Lipophleps Bergr.

Limoniinæ—Continued.
Eriopterini—Continued.
Gnophomyia O. S.
Teucholabis.
Teucholabis O. S.
Gymnastes Brun.
Cryptolabis.
Baeoura Alex.
Erioptera.
Erioptera Meig.
Molophilus Curt.
Styringomyia Lw.

TIPULINÆ

TIPULODINA PAMPANGENSIS sp. nov.

General coloration obscure yellow, marked with black; pleura yellow, with small dark spots; legs black, ringed with white; all basitarsi black, the tips conspicuously snowy white; wings light yellow, with a brown pattern; no dark area in cell M; Rs very short, less than R_{2+3}; R_3 long and extended.

Female.—Length, about 26 millimeters; wing, 18.5.

Frontal prolongation of head ocherous above, brownish black laterally; palpi brownish yellow. Antennæ with the scapal segments ocherous; flagellum broken. Head brownish gray, the frons yellow.

Pronotum brownish black above, yellow laterally. Mesonotal præscutum obscure yellow, almost covered by four blackish stripes that are narrowly margined with dull black; lateral margins of sclerite more pruinose; posterior sclerites of mesonotum dull black, the sides of the postnotum paler. Pleura yellow, with small blackish spots, including one on the otherwise yellow dorsopleural membrane, an area above the fore coxa, another above the meron, and an elongate band on the pleurotergite. Halteres black. Legs with the coxæ yellow, the posterior coxæ more grayish behind; trochanters yellow, marked with darker; fore femora brown, with a broad whitish subterminal ring; fore tibiæ black, with a broad white subterminal ring that is a little greater than the blackened tip; middle femora brown, the tips brownish black; middle tibiæ about as on forelegs; posterior femora brown, the tips blackened; posterior tibiæ black, with two white rings; all basitarsi black, the apical fourth or fifth snowy white; segments two to four white, the terminal segment blackened; setæ of the white rings very small and delicate, snowy white. Wings (fig. 1) with the ground color light yellow, the

brown pattern about as in allied forms; no darkening in cell M. Venation: Rs very short, less than R_{2+3}; R_3 long and extended.

Abdominal tergites reddish brown, blackened medially; on the outer segments the areas widened out so as to restrict the ground color to basolateral triangles, the caudal margins narrowly pale; sternites paler.

LUZON, Pampanga Province, Mount Arayat, October, 1929 (*Rivera*); holotype, female.

Tipulodina pampangensis is distinct from the other described Philippine species in the yellow-tinted wings, without darkening in cell M and with the venational details quite different from *T. luzonica* Alexander. The latter species usually has the tips of the basitarsi similarly pale, but I have seen specimens that were apparently conspecific in which the basitarsi were entirely blackened.

Genus SCAMBONEURA Osten Sacken

Scamboneura OSTEN SACKEN, Berlin. Entomol. Zeitschr. 26, Heft 1 (1882) 95.

At this time I am describing as new three species of this genus and am further describing and illustrating the details of the male hypopygium of *Scamboneura unicolor* Bezzi and *S. plumbea* Alexander. The number of species now known from the Philippines is eleven and a new key to these forms is provided, to supersede the earlier one.[1]

Key to the Philippine species of Scamboneura Osten Sacken.

1. Anterior cord transverse or subtransverse, Rs in approximate alignment with the remaining elements of the cord ..... 2.
   Anterior cord strongly bowed, Rs lying distad of the remaining elements of the cord ..... 4.
2. Anterior cord subtransverse, cell R_5 lying proximad of cell R_4; median præscutal stripe divided by a paler line.
   S. subtransversa sp. nov.
   Anterior cord transverse, cell R_5 lying proximad of cell R_5; when the præscutum is striped, the median vitta is entire ..... 3.
3. Mesonotal præscutum and scutal lobes with plumbeous markings that are narrowly bordered by black ..... *S. primaeva* Alexander.
   Mesonotal præscutum yellowish, immaculate ..... *S. primogenia* sp. nov.
4. Thoracic dorsum strongly pruinose, never polished, the gray coloration forming a discal shield ..... 5.
   Thoracic dorsum not pruinose, either polished or opaque, the præscutal disk with separate stripes (except in *unicolor*) ..... 7.

[1] Philip. Journ. Sci. 33 (1927) 293–294.

5. Thoracic dorsum and pleura uniformly plumbeous.
S. plumbea Alexander.
Thorax not uniformly plumbeous, at least the pleura variegated with pale and dark areas ..... 6.
6. Pleura conspicuously striped with darker....*S. psarophanes* Alexander.
Pleura, especially the sternopleurite, not conspicuously striped with darker ..... *S. banahaoensis* sp. nov.
7. Mesonotal præscutum with three stripes that are polished brown, slightly metallic, bordered by opaque black; pleura pale, distinctly variegated with darker ..... *S. dotata* Osten Sacken.
Mesonotal præscutum without stripes of this nature; pleura uniformly pale ..... 8.
8. General coloration of head and thorax yellow, immaculate.
S. unicolor Bezzi.
Either the præscutum or the head, or both, marked with darker.... 9.
9. Præscutal stripes polished; head unmarked except for an occipital area.
S. faceta Alexander.
Præscutal stripes opaque; occipital area sending a narrow dark vitta cephalad onto the vertex ..... 10.
10. Præscutal stripes ill-defined to subobsolete; male hypopygium not conspicuously enlarged, the eighth sternite without long conspicuous setæ ..... *S. vittivertex* Alexander.
Præscutal stripes distinct; male hypopygium enlarged, the eighth sternite with abundant long reddish setæ.
S. hirtisternata Alexander.

The three species first named, having the anterior cord of the wings transverse or nearly so, have all been discovered since the preparation of the former key (1927).

SCAMBONEURA SUBTRANSVERSA sp. nov.

General coloration yellow, the præscutum with three brown stripes, the median one divided by a brownish yellow vitta; vertex of head with a black median vitta; wings with the elements of the anterior cord in nearly transverse alignment, the inner end of cell R_5 lying slightly proximad of that of cell R_3; abdominal tergites yellow, each with a metallic area at near midlength.

Male.—Length, about 11 millimeters; wing, 9.5.

Female.—Length, about 16 millimeters; wing, 11.5.

Frontal prolongation of head yellow, narrowly dark brown above; mouth parts, with the exception of the infuscated outer segments of the maxillary palpi, pale. Antennal scape yellow, the flagellum nearly uniformly blackened in male, only the outer end of the basal segment being pale; in the female the basal segment is chiefly yellow and the outer ends of the succeeding five or six segments are yellowish; antennæ of male more elon-

gate than that of female, the verticils much shorter than the segments in both sexes. Head with the posterior vertex, occiput, and postgenæ grayish brown, the anterior part of the head orange, with a conspicuous black median vitta extending virtually to the summit of the vertical tubercle.

Pronotum infuscated on cephalic portion, the narrow posterior median portion obscure yellow. Mesonotal præscutum pale yellow, with three shiny brown stripes, the short lateral stripes slightly more bronzy, entire or narrowly bordered by velvety brownish black; the larger wedge-shaped median area conspicuously divided by a brownish-yellow center that does not attain the suture behind; scutal lobes almost covered by extensive dark areas that are quite similar in color to the lateral præscutal stripes; scutellum more or less infuscated; postnotal mediotergite pale whitish yellow, with a ⊥-shaped brown pruinose marking. Pleura pale testaceous yellow, unmarked, somewhat more pruinose dorsally, clearer yellow ventrally. Halteres infuscated, the base of the stem narrowly pale. Legs with the coxæ and trochanters pale; femora yellow; tibiæ and tarsi passing into brown. Wings (fig. 2) tinged with yellow, the prearcular and costal regions deeper yellow; stigma very small, brown; veins black, C, Sc, R, and Cu more yellowish brown. Venation: Anterior cord almost transverse, the proximal end of cell R_5 lying slightly proximad of cell R_3; Rs in approximate alignment with the remainder of cord.

Abdominal tergites yellow, each with a metallic steel-gray or blue median area at near midlength of the segment, these becoming smaller behind and finally obsolete on the outer segments; extreme lateral margins of the segments darkened, interrupted at posterior margin of segment; sternites yellow; hypopygium yellow. Male hypopygium with the caudal margin of the ninth tergite (fig. 23) with a U-shaped notch, the ventral margins set with delicate setæ that pass into small blackened conical spines; sublateral arms on ventral surface terminating in four or five blackened teeth. Outer dististyle irregular in outline. Inner dististyle about as illustrated (fig. 24). Appendage of ninth sternite (fig. 25) narrow, liguliform, very gradually narrowed outwardly, the apex weakly bilobed, the surface of the appendage densely set with microscopic yellow spines that are longer and coarser at tips of lobes. Margins of ninth sternite adjoining the appendage with very long conspicuous yellow setæ. Caudal margin of eighth sternite (fig. 26) evenly rounded, at midwidth with a brush of short stiff black setæ.

LUZON, Rizal Province, Novaliches, June 27, 1929 (*Duyag*); holotype, male; allotype, female, June 28, 1929 (*Duyag*); Pampanga Province, Mount Arayat, October, 1929 (*Rivera*); paratypes, 20 males and females.

SCAMBONEURA PRIMOGENIA sp. nov.

General coloration brownish yellow, the mesonotum unmarked; antennæ of male relatively short, if bent backward extending about to the root of the halteres; wings with Rs in alignment with the other elements of the anterior cord; male hypopygium with the appendage of the ninth sternite a simple slender lobe.

Male.—Length, about 13 millimeters; wing, 13.

Female.—Length, about 14 millimeters; wing, 12.5.

Frontal prolongation of head yellow, the nasus long and conspicuous; palpi pale yellow. Antennæ (male) relatively short, only a little longer than the palpi, if bent backward extending about to the root of the halteres; scape yellow, flagellum black. Head of male yellow, unmarked, of female with indications of a median brown vitta.

Mesonotum brownish yellow, subnitidous, without markings. Pleura somewhat clearer yellow. Halteres dark brown. Legs with the coxæ and trochanters yellow; femora obscure yellow, the outer portions more darkened; tibiæ and tarsi dark brown. Wings (fig. 3) whitish subhyaline; stigma small, brown; veins black, C, Sc, R, and Cu paler. Venation: Rs in alignment with the other elements of the anterior cord; R_{1+2} represented by a spur that is subequal to R_2 alone; R_3 gently arcuate.

Abdomen (male) brownish yellow, the basal tergites and the sternites clearer yellow; in female, abdominal tergites almost entirely deep blue-black, the bases and extreme caudal margins of the segments restrictedly paler. Male hypopygium with the ninth tergite (fig. 27) entirely pale above, the caudal margin with a deep V-shaped notch, the lateral lobes broadly rounded; ventral surface of tergite with a few scattered blackened spicules. Dististyles about as illustrated (fig. 28), the apical beak of the inner style stout and only slightly blackened. Appendage of ninth sternite (fig. 29) a long, slender lobe, appearing as a simple rod-shaped structure, the apex obtuse, the organ fringed with delicate setulæ. Gonapophyses as illustrated (fig. 30).

LUZON, Cagayan Province, Mount Tabuan, May, 1929 (*Rivera*); holotype, male; allotype, female; paratype, female.

Scamboneura primogenia is most closely allied to *S. primaeva* Alexander, differing most evidently in the unvariegated mesonotum. The male sex of *S. primaeva* is still unknown.

SCAMBONEURA BANAHAOENSIS sp. nov.

Most closely allied to *S. psarophanes* Alexander, differing in the details of coloration and structure of the male hypopygium: pleura not conspicuously variegated with darker.

Male.—Length, about 12 millimeters; wing, 11.

Female.—Length, about 16 millimeters; wing, 13.

Antennæ with the flagellum of male blackened, of the female with the tips of the basal segments narrowly pale to produce a weakly bicolorous appearance. Occiput and posterior portion of vertex gray, sending a broad black median vitta almost to the summit of the vertical tubercle, the mark much broader and more distinct than in *psarophanes*.

Præscutal stripes four in number, blackened, separated from one another by yellowish gray to clear gray pruinose interspaces; humeral and lateral portions of the præscutum obscure yellow. Pleura chiefly pale yellow, weakly pruinose but not conspicuously marked with darker, as in *psarophanes*. Legs with the coxæ and trochanters yellow, the cephalic face of the fore coxæ darkened; femora yellowish brown, the tibiæ and tarsi darker. Wings (fig. 4) a little narrower, the anterior cord slightly more bowed; vein and cell 2d A slightly shorter; macrotrichia of veins slightly longer and more conspicuous.

Abdomen with the tergites yellow, conspicuously trivittate with shiny black, the median stripe shiny, interrupted on the anterior ring of the segments and more narrowed on the posterior margin; lateral stripes narrow but continuous; sternites yellow; hypopygium chiefly yellow. Male hypopygium with the caudal margin of the tergite (fig. 31) with a narrow V-shaped notch, that is further produced into a compressed blade. Outer dististyle (fig. 32) narrowed to a slender obtuse lobe. Inner dististyle as illustrated (fig. 33). Appendage of ninth sternite (fig. 34) depressed, the caudal end emarginate, the surface covered with abundant pale yellow setæ that are longer and more conspicuous on the lateral lobes, these latter with a single powerful black seta on outer margin before apex. Caudal margin of eighth sternite slightly emarginate and provided with groups of long conspicuous setæ on either side.

LUZON, Laguna Province, above Ube, altitude 1,625 feet, September 1, 1929 (*McGregor*); holotype, male; allotype, female, in copula. "Resting flat on upper surface of leaf of *Elatostema* (Urticaceæ)."—McGregor; 1 female, August, 1929 (*Rivera*); paratopotype.

SCAMBONEURA PLUMBEA Alexander.

Scamboneura plumbea ALEXANDER, Philip. Journ. Sci. 21 (1922) 379–380.

The type, a female, was from Pauai, received through Prof. C. F. Baker. A male and two additional females were taken at the type locality, altitude 8,000 feet, April 24–26, 1930, by Rivera. The male is herewith described as allotype.

Male.—Length, about 12.5 millimeters; wing, 12.5; antenna, about 4.2.

Antennæ black throughout, unusually short for this sex. Scutellum gray, concolorous with the remainder of mesonotum; præscutum with indications of four darker gray stripes. Abdominal tergites conspicuously dimidiate, the basal third orange yellow, the broad distal ring black to blue-black; sternites more uniformly yellow, the bases brighter and lighter yellow than the apices. Male hypopygium with the tergite (fig. 35) transverse, the base blackened and with abundant delicate setæ; apical lobes yellow, margined with coarse spinous setæ; a median liguliform pale yellow lobe beneath. Outer dististyle (fig. 36) very broad at base, narrowed to a slender obtuse point. Inner dististyle (fig. 37) shaped as in figure, the blackened apical beak slender; a small group of setigerous tubercles on the outer margin near base. Appendage of ninth sternite (fig. 38) conspicuously bilobed, the entire structure densely set with small stellate groups of setulæ, with longer and more conspicuous setæ at the apices of the lobes.

SCAMBONEURA UNICOLOR Bezzi.

Scamboneura dotata unicolor BEZZI, Philip. Journ. Sci. 12 § D (1917) 112.

Specimens from Ube, Laguna Province, Luzon, March 28 to May 31, 1929 (*Duyag; McGregor*); December, 1929 (*Rivera*).

The details of the male hypopygium have never been described and may here be briefly characterized.

Ninth tergite (fig. 39) not heavily chitinized; lateral lobes margined with very delicate setulæ; spines on mesal face of lobes small and weak, merging gradually into marginal setulæ; median lobule compressed. Outer dististyle (fig. 40) pale, flattened, narrowed to a blunt apical point, the outer margin conspicuously dilated. Inner dististyle (fig. 41) a pale blade with numerous retrorse setæ, the apex narrowed to a blunt blackened point. Appendage of ninth sternite (fig. 42) a depressed bilobed structure, the lobes densely set with setulæ.

DOLICHOPEZA (NESOPEZA) HAIGHTENSIS sp. nov.

General coloration testaceous; tibiæ and tarsi white, the tips of the former narrowly darkened; male hypopygium with the tergite small, the margin gently concave, the median portion slightly produced into a minute obtuse lobule.

Male.—Length, about 8 millimeters; wing, 9.5.

Antennæ (male) elongate, if bent backward extending about to one-third the length of the abdomen; flagellar segments elongate-cylindrical, with a dense white pubescence and a few scattered slightly longer black verticils; antennæ pale brownish yellow. Head obscure orange (probably teneral).

Mesonotum testaceous, the præscutum with three reddish stripes. Anterior mesopleura nearly white, the dorsopleural region infuscated. Halteres elongate, pale, the knobs darkened. Legs with the coxæ and trochanters pale; femora dirty white, the tips darkened; tibiæ whitish, the tips narrowly darkened; tarsi white. Wings subhyaline, the stigma darker; veins pale brown; veins beyond the cord with abundant macrotrichia. Venation: Forks of medial field moderately deep, the second and third sections of M_{1+2} subequal, each about two-thirds the length of cell M_1.

Abdomen with the basal segments pale, the outer segments more darkened, especially the tergites. Male hypopygium (fig. 43) small and of simple construction. Ninth tergite small, the caudal margin gently concave, the median portion produced into a minute obtuse lobule; lateral lobes low, the lateral margins thickened beneath, blackened, and here provided with a few blackened spicules. Outer dististyle, *od*, small, slightly flattened.

LUZON, Mountain Province, Benguet, Pauai, altitude 8,000 feet, April 18, 1930 (*Rivera*); holotype, a teneral male.

Dolichopeza (*Nesopeza*) *haightensis* is very different from the other species described from Luzon and Formosa.

Genus MACGREGOROMYIA Alexander

Macgregoromyia ALEXANDER, Philip. Journ. Sci. 40 (1929) 251.

The accession of more material of the genotype, *M. benguetensis* Alexander, together with the discovery of a second species, *M. brevisector*, necessitates the recasting of the generic characters.

Antennæ 12-segmented, the terminal segment elongate, the apical third narrowed into a false thirteenth segment; flagellar segments cylindrical, with unilaterally arranged, inconspicuous

verticils. Maxillary palpi with the terminal segment long and slender (*benguetensis*) or shorter (*brevisector*). Male hypopygium of simple structure, the tergite not heavily chitinized, the caudal margin with a U-shaped median notch, the lobes obtusely rounded.

The two known species may be separated as follows:

1. Rs with the basal section long and arcuated, exceeding three times the second section; tibiæ uniformly darkened or with the tips insensibly or very narrowly pale ..... *M. benguetensis* Alexander.
   Rs with the basal section short, transverse or nearly so, subequal in length to the second section; tibiæ dark, the tips broadly pale yellow. *M. brevisector* sp. nov.

MACGREGOROMYIA BENGUETENSIS Alexander.

Macgregoromyia benguetensis ALEXANDER, Philip. Journ. Sci. 40 (1929) 251–252, pl. 1, fig. 3.

A few additional specimens, representing both sexes, from the type locality, Pauai, Mountain Province, Luzon, altitude 8,000 feet, collected April 13 to 20, 1930, by Rivera.

This series of specimens shows a curious variation in venation of the medial field. A certain number of the specimens show m-cu connecting at the fork of M_{3+4}, as originally figured for the species. One specimen shows M_3 fused for a short distance at base with M_{1+2}, as in the genus *Nephrotoma*, m-cu in this instance connecting with M_4 a short distance beyond its origin. In some specimens, the free tip of Sc_2 and R_{1+2} are approximated or actually fused at the wing margin, closing or narrowing cell Sc_2. The knobs of the halteres are only slightly darkened in almost all specimens.

MACGREGOROMYIA BREVISECTOR sp. nov.

General coloration yellow, the præscutum with three brown stripes; antennal scape yellow, the flagellum black; legs chiefly dark brown, the tips of the tibiæ broadly yellow; wings whitish, the cells beyond the cord chiefly infumed, variegated with areas of the ground color; basal section of Rs short and nearly transverse; tip of R_{1+2} atrophied; m-cu at near one-third the length of M_{3+4}; cell 2d A narrow.

Male.—Length, about 10.5 millimeters; wing, 11.3.

Frontal prolongation of head obscure yellow above, darker beneath; nasus elongate; palpi with the basal three segments brownish black, the terminal segment yellow, shorter than the combined second and third segments. Antennæ with the scape yellow, the flagellum black. Head brown, very narrowly paler

on the orbits; antennal fossæ with a curved blackened line behind.

Mesonotal præscutum yellow, the interspaces more obscured, the disk with three dark brown stripes, the central portion of the median stripe somewhat paler; scutal lobes darkened, the median region yellow; scutellum and postnotal mediotergite testaceous brown. Pleura yellow, variegated with brown on the sternopleurite, anepisternum, and meron. Halteres very long, yellow, the knobs dark brown. Legs with the coxæ obscure yellow, the outer face of the hind coxæ darkened; trochanters yellow; femora dark brown, paler basally; tibiæ brownish black, the extreme base pale, the tips broadly and conspicuously light yellow, this including about the distal fifth or sixth of the segment; tarsi brownish black; tibial spurs very small. Wings (fig. 5) petiolate at base; ground color of basal cells whitish, those beyond the cord suffused with brown, with whitish areas in their proximal portions, including a prestigmal and a poststigmal area; bases of cells R_3, R_5, M_1, 2d M_2, M_3, and M_4, with smaller pale areas; entire central portion of cell 1st M_2 pale; cells C and Sc light brown; stigma and a conspicuous circular cloud on the anterior cord darker brown; veins Cu, 2d A, and m-cu narrowly seamed with brown; outer margin of cell 1st A dusky; veins black, those in the costal region paler. Venation: As in *benguetensis,* with the following exceptions: Basal section of Rs short and nearly transverse, weakly angulated at midlength, about equal in total length to the second section of Rs; tip of R_{1+} atrophied; cell 1st M_2 roughly elongate-oval in outline; basal section of M_{2+4} a trifle shorter than the second section; basal section of M_3 subequal to or shorter than m-cu; m short; cell 2d A very narrow.

Abdominal tergites black, the segments narrowly ringed with obscure yellow, before the narrowly darkened apices; sternites more uniformly obscure yellow; subterminal segments and hypopygium more uniformly darkened. Male hypopygium with the ninth tergite (fig. 44) pale, the caudal margin with a deep conspicuous U-shaped notch, the lateral lobes obtusely rounded, provided with an additional very small lateral lobule. Dististyles as illustrated (figs. 45 and 46).

LUZON, Mountain Province, Benguet, Pauai, altitude 8,000 feet, April 18, 1930 (*Rivera*); holotype, male; allotype, female, April 26, 1930; paratypes, 4 males, April 21 to 26, 1930; Bontoc Subprovince, Mount Data, April 29, 1930, resting on a leaf (*Rivera*), paratype, male.

Macgregoromyia brevisector is very distinct from the genotype, *M. benguetensis* Alexander; both species are known only from the highest mountains of northern Luzon.

LIMONIINÆ

LIMONIINI

LIMONIA (LIMONIA) LIGAYAI sp. nov.

General coloration reddish testaceous, the mesonotum variegated with brown; antennæ black; thoracic pleura with a longitudinal black stripe; legs and halteres darkened; wings tinged with blackish; Sc long, Sc_2 at the tip of Sc_1; male hypopygium with the ventral dististyle small, the rostral prolongation very long and slender; dorsal dististyle setiferous on basal three-quarters; gonapophyses appearing as blackened, weakly sinuous horns.

Male.—Length, about 4.2 to 4.4 millimeters; wing, 5.5 to 5.6.

Female.—Length, about 5 millimeters; wing, 5.3 to 5.5.

Rostrum and palpi black. Antennæ black throughout; flagellar segments short-cylindrical, with very short apical pedicels; segments covered with a short white pubescence and with relatively short unilaterally arranged verticils; terminal segment longer than the penultimate, pointed at apex. Head brownish gray.

Mesonotum light reddish testaceous, the præscutum with three ill-delimited brown stripes, the scutal lobes extensively darkened. Pleura clear yellow ventrally, the dorsal portions chiefly occupied by a narrow longitudinal black stripe; dorsopleural region darkened. Halteres brownish black, the base of the stem narrowly yellow. Legs with the coxæ and trochanters light yellow; femora light yellow basally, the tips broadly brownish black, broadest on the forelegs where it includes more than the outer three-fourths, narrowest on the posterior legs where approximately the outer fifth is darkened; tibiæ pale brown, the tips a little darkened; tarsi brown, the posterior tarsi a trifle paler. Wings (fig. 6) with a strong blackish tinge, the small oval stigma darker brown; veins brownish black. Costal fringe of both sexes relatively long and conspicuous. Venation: Sc long, Sc_1 ending beyond midlength of Rs, Sc_2 at its tip; Rs arcuated to weakly angulated and short-spurred at origin; free tip of Sc_2 nearly its own length before R_2; cell 1st M_2 closed; m-cu close to fork of M; vein 2d A long.

Entire abdomen dark brown. Male hypopygium (fig. 47) with the tergite, 9*t*, unusually long, narrowed outwardly, the

caudal end very gently emarginate. Basistyle, *b*, with the ventromesal lobe basal in position, stout. Ventral dististyle, *vd*, small, appearing as an oval fleshy lobe provided with long coarse setæ; rostral prolongation very long and slender, gently curved; spines pale, two in number, basal in position. Dorsal dististyle long and slender, the long acute apex decurved; basal three-fourths of style with abundant appressed setæ. Gonapophyses, *g*, appearing as blackened, weakly sinuous horns, the tips subacute. Ædeagus, *a*, stout, bifid at tip.

LUZON, Mountain Province, Benguet, Pauai, altitude, 8,000 feet, April 15 to 26, 1930 (*Rivera*); holotype, male; allotype, female; paratypes, 7 males and females; Laguna Province, above Ube, altitude 1,500 feet, February 3 to 9, 1930 (*Rivera*); paratypes, 2 males.

Limonia (*Limonia*) *ligayai* is named in honor of Mr. Macario Ligaya, artist of the Philippine Bureau of Science, to whom I express my indebtedness for his coöperation in preparing the plates of figures accompanying this series of papers. The species is clearly defined by the combination of characters diagnosed above.

LIMONIA (LIBNOTES) NEOFAMILIARIS sp. nov.

General coloration ocherous, the mesonotal præscutum darkened in front; head black; wings whitish subhyaline, cells C and Sc more yellowish brown; stigma dark brown; abdominal tergites dark brown, the sternites and hypopygium yellow.

Male.—Length, about 8 millimeters; wing, 10.4.

Rostrum and palpi black. Antennæ black throughout; flagellar segments becoming more slender and elongate outwardly; longest verticils unilaterally arranged and much exceeding the segments; terminal segment longer than the penultimate. Head black, sparsely pruinose; anterior vertex reduced to a narrow strip.

Pronotum darkened medially, paling to yellow on sides. Mesonotum ocherous, the præscutum vaguely darker medially, especially on anterior half. Pleura ocherous, vaguely marked with more reddish ocherous on the sternopleurite. Halteres dirty white, the knobs darkened. Legs with the coxæ and trochanters yellow; remainder of legs light brown. Wings (fig. 7) whitish subhyaline, cells C and Sc more yellowish brown; stigma relatively small, trigonal, dark brown; veins black, the prearcular and costal veins paler. Venation: Sc_1 ending beyond r-m, Sc_2 some distance from its tip; Rs long, gently sinuous, in alignment with the basal section of R_{4+5} and approximately four times

as long; free tip of Sc_2 and R_2 in transverse alignment; cell 1st M_2 small, m-cu at midlength; anal veins divergent.

Abdominal tergites dark brown, the sternites yellow; hypopygium pale. Male hypopygium (fig. 48) with the tergite, 9*t*, transverse, the caudal margin with a low V-shaped emargination, the lateral lobes with long conspicuous setæ. Basistyle, *b*, much smaller than the ventral dististyle, *vd;* rostral prolongation of latter stout, slightly blackened, the two spines unequal in diameter, the outermost a little shorter and stouter. Dorsal dististyle a powerful sickle. Gonapophyses, *g*, with the outer margin toothed.

LUZON, Mountain Province, Benguet, Mount Santo Tomas, above Baguio, altitude over 5,000 feet, October 9, 1929 (*Duyag*); holotype, male.

According to Edwards, *Limonia* (*Libnotes*) *familiaris* (Osten Sacken) has the male hypopygium with elongate basistyles and small ventral dististyles, thus differing from the two species described herein as *subfamiliaris* sp. nov. and *neofamiliaris* sp. nov., both of which have short basistyles and a large fleshy ventral dististyle. The present species differs from *subfamiliaris* by the size, coloration, and details of venation.

LIMONIA (LIBNOTES) SUBFAMILIARIS sp. nov.

General coloration fulvous yellow, the thorax unmarked; head blackish gray; wings yellowish subhyaline, the base and costal region more yellowish; stigma small, dark brown; R_2 and free tip of Sc_2 in transverse alignment; male hypopygium with the spines of the rostral prolongation of the ventral dististyle very unequal, the innermost reduced to a slender seta.

Male.—Length, about 6.5 millimeters; wing, 9.

Rostrum dark brown; palpi black. Antennæ brownish yellow, the incisures clearer yellow; verticils of segments very long, arranged chiefly unilaterally; terminal segment elongate. Head blackish gray, the orbits narrowly light gray; anterior vertex very narrow.

Thorax light fulvous yellow, entirely unmarked. Halteres pale. Legs with the coxæ and trochanters fulvous yellow; femora brownish yellow, gradually darkened outwardly, the extreme tips vaguely paler; tibiæ and tarsi dark brown. Wings (fig. 8) yellowish subhyaline, the prearcular and costal regions more yellowish; stigma small, dark brown, subcircular; veins dark brown, paler in the flavous areas. Venation: Sc long; Rs nearly straight, in alignment with the basal section of R_{4+5}

and approximately twice as long; free tip of Sc_2 and R_2 in transverse alignment; cell 1st M_2 relatively small; m-cu at from near one-third to two-fifths the length of the cell.

Abdomen fulvous, the hypopygium pale. Male hypopygium with the tergite transverse, its caudal margin with a shallow V-shaped emargination, the lobes densely set with conspicuous setæ, the outer ones larger and coarser. Rostral prolongation of ventral dististyle stout, the two spines very unequal in size, the outer stout, the inner nearly as long but reduced to a mere seta. Gonapophyses with the outer margin before apex microscopically toothed.

LUZON, Pampanga Province, Mount Arayat, October, 1929 (*Rivera*); holotype, male.

LIMONIA (LIBNOTES) PERPARVULA sp. nov.

Size very small (wing, male, less than 4.5 millimeters); general coloration yellow, the præscutum variegated with brown; knobs of halteres blackened; legs brown, the tips of the femora narrowly yellow; wings grayish, the stigma a little darker than the ground color; male hypopygium with the ventral dististyle entirely without rostral spines.

Male.—Length, about 3.5 millimeters; wing, 4.3.

Rostrum and palpi black. Antennæ black throughout; flagellar segments with stout glabrous apical necks that are concolorous with the remainder of the segment; segments with long, unilaterally arranged verticils. Head dark, the anterior vertex and orbits gray; anterior vertex very narrow.

Mesonotal præscutum yellow, with a median dark brown stripe; lateral margins of the sclerite behind the pseudosutural foveæ slightly darkened; posterior sclerites of mesonotum more testaceous yellow. Pleura yellow. Halteres yellow, the knobs blackened. Legs with the coxæ and trochanters yellow; femora dark brown, the tips narrowly and abruptly yellow; tibiæ and tarsi light brown, the terminal segments of the latter darkened; claws long and slender, each with a long basal spine. Wings (fig. 9) grayish, prearcular region and cells C and Sc yellow; stigma oval, very slightly darker than the ground color; veins brown, C, Sc, and R more yellowish. Venation: Sc_1 ending about opposite midlength of the basal section of R_{4+5}, Sc_2 at its tip; Rs relatively short and straight; distal end of R_1 curving strongly toward R_{2+3} but the free tip of Sc_2 in approximate alignment with R_2; m-cu at or just beyond midlength of cell 1st M_2; vein 2d A converging slightly towards 1st A at origin.

Abdominal segments dark brown, the caudal margins narrowly yellow; hypopygium chiefly pale. Male hypopygium (fig. 49) with the caudal margin of the tergite, 9*t*, transverse. Basistyle, *b*, long, the ventromesal lobe very low and obtuse. Dorsal dististyle a nearly straight rod. Ventral dististyle fleshy, the oval body set with long coarse setæ, the stout rostral prolongation without evident spines; on face of style near base of prolongation with a corrugated plate. Gonapophyses, *g*, with the mesal apical lobes very long and slender.

LUZON, Pampanga Province, Mount Arayat, October, 1929 (*Rivera*); holotype, male.

Limonia (*Libnotes*) *perparvula* is very distinct from all regional species of the subgenus.

LIMONIA (LIBNOTES) ELATA sp. nov.

General coloration fulvous; hypopygium black; femora yellow, tipped with black; wings relatively narrow; veins beyond cell 1st M_2 elongate; cell 2d A narrow; male hypopygium with the dorsal dististyle a yellow cultriform blade.

Male.—Length, about 11 millimeters; wing, 14.5.

Rostrum and palpi black, the former of moderate length only. Antennæ brown; flagellar segments oval, more slender and attenuate outwardly, each with a seta of unusual length, unilaterally arranged. Head reddish brown, the front and anterior vertex more infuscated; anterior vertex (male) reduced to a linear strip.

Thorax opaque fulvous, without evident markings. Halteres fulvous, the knobs brownish black. Legs with the coxæ and trochanters fulvous; femora yellow, the tips conspicuously blackened; tibiæ and basitarsi yellow, narrowly darkened at tips; remainder of tarsi dark brown. Wings (fig. 10) much narrower than in *termitina,* all cells correspondingly narrowed and more elongate; membrane with a conspicuous brown suffusion, quite as in *termitina;* stigma (male) large, elongate, brown, the costal margin being paler than the stigma; extreme wing tip dark brown; veins dark brown. Venation: R_2 joining R_1 at a more abrupt angle than in *termitina;* outer radial veins deflected strongly caudad at tips; cell 1st M_2 long and narrow, the veins beyond it unusually elongate, the cell being about one-half of vein M_3 beyond it; m-cu just before midlength of the cell; cell 2d A narrow, at near midlength very closely approaching vein 1st A.

Abdomen fulvous, the hypopygium blackened. Male hypopygium (fig. 50) with the caudal margin of the tergite, 9*t*, nearly straight or very slightly emarginate. Basistyles, *b*, large, especially the ventromesal lobe. Ventral dististyle, *vd*, small, oval, with very long coarse setæ; rostral prolongation elongate, yellow, at base with two approximated spines of nearly equal length, a little exceeding one-half the length of the prolongation; on face of style near base of prolongation with a tubercle that bears two very long slender spinous setæ. Dorsal dististyle, *dd*, stout, yellow, the apex subcultriform.

LUZON, Pampanga Province, Mount Arayat, altitude 3,100 feet, October, 1929 (*Rivera*); holotype, male.

Limonia (*Libnotes*) *elata* is most similar to *L.* (*L.*) *termitina* (Osten Sacken), differing in the narrow wings and details of venation.

LIMONIA (DISCOBOLA), probably ARGUS (Say).

Limnobia argus SAY, Long's Exped., Append. (1824) 358.

A female specimen, taken at Pauai, Mountain Province, altitude 8,000 feet, April 11, 1930, by Rivera, probably belongs to this widely distributed crane fly.

LIMONIA (DICRANOMYIA) BENGUETENSIS sp. nov.

Belongs to the *morio* group; abdominal segments black, their caudal margins yellow; male hypopygium with the caudal margin of tergite bearing two slender lobes; basistyle with the ventromesal lobe stout, dark-colored; outer dististyle bifid at apex; rostral spine of ventral dististyle apparently lacking.

Male.—Length, about 4.8 millimeters; wing, 5.8.

Rostrum, palpi, and antennæ black; flagellar segments oval, becoming more slender and elongate outwardly. Head black, the anterior vertex silvery.

Mesonotum polished black, the median region of the scutum more pollinose. Pleura black, chiefly covered with a conspicuous silvery pruinosity, the ventral sternopleurite and ventral anepisternum polished black. Halteres yellow, the knobs brownish black. Legs with the fore coxæ darkened, the other coxæ and all trochanters obscure yellow; femora obscure yellow, passing into brownish black at tips; tibiæ and tarsi black. Wings (fig. 11) with a strong brown tinge, the oval stigma darker brown; veins dark brown. Venation: Sc_1 very long, ending just before the origin of Rs; m-cu at fork of M; cell 2d A wide.

Abdomen black, the segments broadly ringed caudally with yellow; terminal segments, including the hypopygium, more uni-

formly blackened. Male hypopygium (fig. 51) with the tergite, 9*t*, transverse, the caudal margin produced into two slender lobes that are separated by a rounded notch. Ventromesal lobe of basistyle, *b*, relatively stout, darkened, provided with three powerful fasciculate setæ, two at apex; basistyle without other armature of tubercles and setiferous groups, as in *nesomorio*. Dorsal dististyle slender, expanded and bifid at apex. Ventral dististyle, *vd*, oval, with long coarse setæ, gradually narrowed to the elongate rostral prolongation; rostral spine lacking or reduced to a tiny tubercle (possibly longer and broken in the unique type). Gonapophyses, *g*, darkened, the mesal apical lobe short. Ædeagus broad, the lateral margins fringed with delicate curved setæ.

LUZON, Mountain Province, Benguet, Mount Santo Tomas, above Baguio, over 5,000 feet, October 9, 1929 (*Duyag*); holotype, male.

Limonia (*Dicranomyia*) *benguetensis* is quite distinct from the Formosan *L.* (*D.*) *nesomorio* (Alexander), which seems to be its closest relative.

LIMONIA (GERANOMYIA) BIFIDARIA sp. nov.

General coloration yellow, variegated with brown; body stout; rostrum black, relatively short; femora and tibiæ dark brown; wings grayish yellow, with a sparse brown pattern; Sc long; cell 1st M_2 closed; male hypopygium with the ventral dististyle large and fleshy, the rostral prolongation small, with two closely approximated spines; gonapophyses with the mesal apical lobe conspicuously bidentate.

Male.—Length, excluding rostrum, about 7 millimeters; wing, 8; rostrum, about 2.7.

Rostrum relatively short and stout, black, including the palpi. Antennæ short, black throughout, the flagellar segments oval, with inconspicuous verticils. Head blackish, the anterior vertex with a narrow silvery median line.

Pronotum brown medially above, more yellowish laterally. Mesonotal præscutum yellow, brightest laterally, with three brown stripes, the median stripe becoming obsolete before the suture, the laterals crossing the suture onto the scutal lobes; median region of scutum and the scutellum more yellowish; postnotal mediotergite more plumbeous, paler medially in front and more narrowly so on lateral margins. Pleura greenish testaceous, the anepisternum and dorsopleural membrane extensively infuscated. Halteres pale, strongly tinged with

green. Legs with the coxæ and trochanters greenish yellow; femora dark brown, the bases yellowish; tibiæ black; tarsi paling to yellowish brown, the outer segments darker. Wings (fig. 12) relatively narrow, with a strong grayish yellow ground color, very sparsely patterned with darker, including three small subcostal areas before the larger stigma; very narrow and indistinct seams along cord and outer end of cell 1st M_2, and at end of vein R_3; veins pale, darker in the clouded areas. Venation: Sc long, Sc_1 ending at near two-thirds the length of Rs, Sc_2 close to its tip; a supernumerary crossvein in cell Sc; cell 1st M_2 long and relatively narrow; m-cu at fork of M.

Abdomen brownish yellow, the tergites darker. Male hypopygium (fig. 52) with the tergite transverse, the lobes low and obtuse, with conspicuous marginal setæ. Basistyle, *b*, small, the ventromesal lobe large. Ventral dististyle, *vd*, very large and fleshy, the rostral prolongation small, the two spines arising very close together from small basal tubercles; spines slightly unequal, the inner a trifle longer, gently curved. Dorsal dististyle strongly curved, the narrowed acute tip slightly upcurved. Gonapophyses, *g*, appearing as conspicuous flattened plates, the mesal apical lobe conspicuously bidentate.

LUZON, Mountain Province, Benguet, Pauai, altitude 8,000 feet, April 18, 1930 (*Rivera*); holotype, male; paratypes, 3 males and females, April 21 to 26, 1930 (*Rivera*).

Limonia (*Geranomyia*) *bifidaria* is readily told by the structure of the male hypopygium, especially the gonapophyses.

LIMONIA (GERANOMYIA) PLEUROPALLORIS sp. nov.

General coloration of mesonotum polished black, the lateral margins of the præscutum yellow; an opaque blackish pruinose area before the suture; pleura yellow, only sparsely pruinose; male hypopygium with the gonapophyses broad, the setæ restricted to the outer half, very delicate.

Male.—Length, excluding rostrum, about 5.5 to 5.8 millimeters; wing, 5.5 to 6; rostrum, 2.8 to 3.

Female.—Length, excluding rostrum, about 6 to 7 millimeters; wing, 6.2 to 7; rostrum, 2.9 to 3.

Rostrum black. Antennæ black. Anterior vertex silvery, the remainder of head dorsally gray.

Mesonotal præscutum with the disk polished black, with an opaque blackish pruinose area on the lateral margin, the remainder of the lateral portions, including the humeral and a presutural area, yellow; scutal lobes black; median region of scutum

and the scutellum chiefly yellow, the latter margined with dusky; postnotal mediotergite black, pruinose, the pleurotergite with a conspicuous blackish area. Pleura pale yellow, with a sparse whitish bloom, the anepisternum and sternopleurite deeper yellow. Halteres greenish yellow. Legs with the coxæ and trochanters yellow; remainder of legs brownish yellow, the terminal tarsal segments blackened. Wings (fig. 13) grayish, the small stigma slightly darker, ill-defined; veins brown. Venation: A supernumerary crossvein in cell Sc at near two-thirds the length; cell 1st M_2 closed; m-cu about one-half its length beyond the fork of M.

Abdominal tergites obscure brownish yellow, clearer yellow laterally; sternites clear yellow, the incisures narrowly dark brown; hypopygium yellow. Male hypopygium with the gonapophyses much broader than in either *argentifera* or *nigronotata*, the setulæ very delicate and restricted to the outer half or less.

LUZON, Laguna Province, Calamba, April 6, 1930 (*McGregor*); holotype, male; allotype, female; paratypes, 4 males and females. "Resting on upper surface of leaf of a small *Ficus* shrub, which overhung a small stream."—McGregor.

Limonia (*Geranomyia*) *pleuropalloris* is related to *L.* (*G.*) *argentifera* (de Meijere) and *L.* (*G.*) *nigronotata* (Brunetti), differing most evidently in the præscutal pattern, the clearer yellow mesopleura, and the details of structure of the male hypopygium, as the broader gonapophyses with the setulæ very small and delicate, restricted to the distal half.

LIMONIA (DOANEOMYIA) PAMPANGENSIS sp. nov.

General coloration light brown; legs black, the tibiæ with the base and apex broadly and subequally white; tarsi snowy white; wings with a dusky tinge; stigma small; Sc long, ending shortly before the origin of Rs.

Male.—Length, about 5 millimeters; wing, 5.4 to 5.5.

Female.—Length, about 5.3 millimeters; wing, 5.5.

Rostrum reddish brown; palpi black. Antennæ relatively elongate, black; flagellar segments oval, with long apical pedicels. Head light brown, the center of the vertex darker.

Mesonotum light brown, subnitidous, without distinct markings, except that in cases the præscutum is more darkened medially. Pleura more testaceous yellow, the ventral sternopleurite a little darker. Halteres elongate, dark brown. Legs with the coxæ and trochanters ocherous; femora black; tibiæ black, the base and apex rather broadly white, the amount subequal

at either end; tarsi white, the outer segments more yellowish. Wings (fig. 14) with a dusky tinge; stigma very small, subcircular; veins dark brown. Venation: Sc long, Sc_1 ending shortly before origin of Rs, Sc_2 far from the tip of Sc_1, the latter subequal to or longer than Rs; cell 2d M_2 deep; m-cu at or beyond the fork of M, nearly transverse or oblique, longer to much longer than the distal section of Cu_1; cell 1st A relatively long and narrow; no vestige of either Cu_2 or 2d A.

Abdomen dark brown, including the hypopygium. Male hypopygium with the rostral spines much longer and more conspicuous than in *tahitiensis* (Alexander).

LUZON, Pampanga Province, Mount Arayat, October, 1929 (*Rivera*); holotype, male; allotype, female; paratypes, 2 males.

The discovery of members of the otherwise strictly Australasian group *Doaneomyia* in the Philippine Islands is a matter of great interest. *Limonia* (*Doaneomyia*) *pampangensis* is closest to *L.* (*D.*) *albitarsis* (Edwards), of New Hebrides, differing especially in the details of venation and coloration.

LIMONIA (DOANEOMYIA) PAMPANGENSIS MAQUILINGIA subsp. nov.

A slightly different race having the white pattern at base of all tibiæ in both sexes much narrower, approximately one-half as wide as the white apex.

LUZON, Laguna Province, Mount Maquiling, September 14, 1929 (*Rivera*); holotype, male; allotype, female; paratype, female.

LIMONIA (THRYPTICOMYIA) OCTOSETOSA sp. nov.

Size small (wing not exceeding 5 millimeters); proximal ends of basitarsi darkened; male hypopygium with the ninth tergite deeply emarginate, each lateral lobe with about four powerful marginal setæ; ventromesal lobe of basistyle without a modified apical seta; mesal apical lobe of each gonapophysis relatively slender, darkened.

Male.—Length, about 4.5 to 5 millimeters; wing, 4 to 5.

Female.—Length, about 4 to 4.3 millimeters; wing, 4 to 4.5.

General appearance much as in *apicalis* (Wiedemann). Antennæ relatively elongate, in male, if bent backward extending to beyond base of abdomen. Mesonotum light yellowish brown, the median region of præscutum and the scutal lobes darker. Proximal ends of basitarsi darkened, this somewhat narrower on the forelegs. Wings (fig. 15) with the apex only slightly darkened. Venation: Sc_1 ending opposite or shortly before origin of Rs; Sc_2 variable in position, in some cases far from tip,

in others much nearer tip; m-cu beyond midlength of cell 1st M_2, the inner end of the latter arcuated.

Male hypopygium (fig. 53) differing in all details from allied regional species. Ninth tergite, 9*t*, deeply notched, the lateral lobes each with about four powerful marginal setæ, the most lateral largest, in cases with an additional median seta. Mesal lobe of basistyle, *b*, relatively stout, without a conspicuous elongate apical seta (as in *microstigma* Alexander and *unisetosa* Alexander). Spines of the rostral prolongation of the ventral dististyle, *vd*, small, the basal enlargements very small to virtually lacking; setæ of apex of rostral prolongation small and relatively insignificant, on the outer margin confined to the extreme end. Gonapophyses, *g*, with the mesal apical lobe long and slender, darkened.

LUZON, Pampanga Province, Mount Arayat, October, 1929 (*Rivera*); holotype, male; allotype, female; paratypes, several of both sexes.

Limonia (*Thrypticomyia*) *octosetosa* is most readily told by the structure of the male hypopygium.

HELIUS (EURHAMPHIDIA) DIACANTHUS sp. nov.

General coloration yellow, the mesonotal præscutum with a median brown stripe; femoral tips and tibial bases broadly snowy white, the amount subequal; wings with a faint dusky tinge, cells C and Sc darker; vein 2d A relatively short; outer dististyle and lateral ends of tergite both bispinous.

Male.—Length, about 5 millimeters; wing, 5.5 to 5.7.

Rostrum a little longer than the head, brownish black; palpi black. Antennæ with the scapal segments pale yellow, the flagellum brownish black; antennæ of moderate length, the flagellar segments long-oval, the outer ones becoming more slender and attenuate. Head gray.

Mesonotum yellow, the præscutum with a median dark brown stripe; remainder of notum yellow, the scutal lobes conspicuously darkened; scutellum infuscated, narrowly paler apically; postnotal mediotergite dark brown, narrowly paler laterally. Pleura yellow. Halteres brown, the base of the stem narrowly pale yellow. Legs with the coxæ and trochanters pale yellow; femora brown, paler at base, deepening outwardly, the tips broadly snowy white; tibiæ black, the base broadly white, a trifle narrower than the femoral tip, the apex broadly white, about three times as extensive as the pale base; tarsi snowy white, the terminal two segments darkened. Wings (fig. 16) with a faint dusky tinge, cells C, Sc, and extreme base of Cu more darkened;

stigma oval, dark brown; veins brownish black. Venation: As in *perelegans*, with the following differences: Sc longer, both Sc_1 and Sc_2 ending about opposite one-fourth the length of the distal section of Rs; basal section of Rs longer; vein 2d A shorter.

Abdominal tergites brown, the subterminal segments darker brown; hypopygium brighter. Male hypopygium (fig. 54) with the lateral arms of the tergite, 9*t*, conspicuously bispinous, the small lateral arm slender and strongly curved. Outer dististyle, *od*, a curved chitinized rod, bidentate at tip.

LUZON, Mountain Province, Benguet, Pauai, altitude 8,000 feet (*Rivera*); holotype, male, April 24, 1930; paratype, male, April 11, 1930; paratypes, 4 males and females, April 22 to 27, 1930 (*Rivera*).

There are several species of *Eurhamphidia* in the Austro-Oriental fauna which have the genua broadly white. The present species differs from *Helius* (*Eurhamphidia*) *abnormalis* (Brunetti) in the details of structure of the male hypopygium, especially of the lateral arms of the tergite, 9*t*, and the outer dististyle, *od* (fig. 55). It seems to be more closely allied to *H.* (*E.*) *perelegans* Alexander (Formosa) which is still known only in the female sex, differing most evidently in the coloration of the body, wings, and legs, as the darkened costal region of the wings and the unusual amount of white on the bases of the tibiæ.

HEXATOMINI

ADELPHOMYIA LUZONENSIS sp. nov.

General coloration obscure yellow, the præscutum with dark brown lateral stripes, the median stripe obsolete or nearly so; dorsal thoracic pleurites darkened; legs yellow, the tips of the femora and tibiæ dark brown; wings yellowish gray, with a conspicuous brown pattern, including spots beyond arculus, origin of Rs, along cord and outer end of cell 1st M_2 and on Sc_2; R_2 at fork of R_{3+4}.

Female.—Length, about 5 millimeters; wing, 5.

Rostrum and palpi dark brown. Antennæ with the scapal segments dark brown, the flagellum much paler; flagellar segments short-oval, becoming more elongate outwardly, with conspicuous verticils that exceed the segments in length. Head obscure yellow, the central portion of the vertex extensively blackened.

Pronotum testaceous above, blackened laterally. Mesonotal præscutum obscure yellow, with dark brown lateral stripes, the

median stripe obsolete or nearly so; scutal lobes dark brown; median region of scutum and extreme base of scutellum obscure yellow; remainder of scutellum and postnotal mediotergite brownish black. Pleura with the dorsal portion dark brown, including the fore coxæ, the remaining coxæ and ventral pleurites yellow. Halteres pale yellow, the knobs infuscated. Legs with the trochanters yellow; femora yellow, the tips narrowly but conspicuously blackened; tibiæ yellow, the tips narrowly brownish black; basitarsi yellow, the tips and remainder of tarsi dark brown. Wings (fig. 17) yellowish gray, the prearcular and costal regions light yellow; a conspicuous brown pattern, distributed as follows: Stigma, bases of cells R and M, Sc_2, along cord and outer end of cell 1st M_2; veins pale, darker in the infuscated areas. Macrotrichia in cells R_3 to M_4, inclusive. Venation: Rs angulated and conspicuously spurred at origin; R_2 at fork of R_{3+4}; cell M_1 present; m-cu at near midlength of cell 1st M_2.

Abdominal tergites dark brown, the sternites obscure yellow, the subterminal sternite darkened. Ovipositor with the tergal valves horn-yellow, upcurved.

LUZON, Mountain Province, Benguet, La Trinidad, below Baguio, altitude 4,800 feet, in open parklike area, March, 1930 (*Rivera*); holotype, female.

Adelphomyia luzonensis is most nearly allied to *A. issikina* Alexander (Formosa), differing especially in the smaller size and details of coloration and venation. The dusky color of the posterior cells of the wing is much less intense than in *issikina* and there is a darkened seam on Sc_2.

EPIPHRAGMA SUBCRENULATA sp. nov.

General coloration brown, the pleura more yellowish beneath; head light ashen gray; halteres brown; legs yellow; wings light brown, the costal region more yellowish, the crossveins and deflections narrowly seamed with brown; axillary region of wing only feebly incised; a series of supernumerary crossveins in cell C but no such element in cell Cu; m-cu more than its own length beyond the fork of M.

Female.—Length, about 8.5 millimeters; wing, 7.3.

Rostrum and palpi black. Antennæ with the scape pale, pruinose, the fusion segment obscure yellow, remainder of flagellum black. Head light ashen gray above, passing into brown on the sides and beneath.

Mesonotal præscutum depressed, light testaceous brown to slightly pruinose, a little paler than the chestnut-brown lateral

portions; scutellum and postnotum slightly pruinose, the latter darkened behind. Pleura infuscated above, the ventral sclerites more yellowish. Halteres elongate, brown. Legs with the coxæ and trochanters yellow; remainder of legs yellow, the femora a very little darker. Wings (fig. 18) light brown, the prearcular and costal regions more yellowish, the coloration continued to beyond the wing tip as large marginal spots at ends of the cells; a restricted brown pattern, appearing as narrow seams at origin of Rs, along cord and outer end of cell 1st M_2, on the supernumerary crossveins and spurs in cell C, and as marginal clouds at ends of all longitudinal veins, those at R_3, R_4, and 2d A most extensive. Axillary region of wing only slightly incised. Venation: A series of about eight supernumerary crossveins and spurs in cell C; cell R_3 relatively deep, the inclosing veins parallel or nearly so; m-cu more than its own length beyond the fork of M; no supernumerary crossvein in cell Cu.

Abdominal segments brownish yellow, narrowly darkened laterally.

LUZON, Mountain Province, Benguet, Mount Santo Tomas, above Baguio, altitude over 5,000 feet, October 9, 1929 (*Duyag*); holotype, female.

Epiphragma subcrenulata requires comparison only with *E. crenulata* Alexander and *E. cinereinota* sp. nov., likewise from the mountains of northern Luzon. From *crenulata* it differs most evidently in the feeble incision of the wing axilla and the details of venation. It differs from *cinereinota* in the body coloration and the nature of the axillary incision.

EPIPHRAGMA CINEREINOTA sp. nov.

General coloration of dorsum of head and thorax light ashen gray, the remainder brown and yellow; antennæ (female) 15-segmented, the fusion segment with only two segments; wings light yellow, with a restricted brown pattern; supernumerary crossveins and spurs in cell C relatively few in number; m-cu at or close to the fork of M; axillary crenulation moderately conspicuous.

Female.—Length, about 10 millimeters; wing, 9.5.

Rostrum and palpi small, black. Antennæ with the scape and fusion segment of flagellum light yellow, the remainder black; antennæ 15-segmented, there being only two segments involved in the basal fusion, the second of these darkened at apex; in *crenulata* there are three segments distinctly involved in the

fusion, all pale in color. Head above light ashy, more infuscated behind and on the sides.

Mesonotum chiefly light ashy, the præscutum in front and on sides abruptly brownish yellow. Pleura yellow, darker behind. Halteres long, brownish yellow, the knobs infuscated. Legs with the coxæ and trochanters pale yellow; remainder of legs obscure yellow, the terminal tarsal segments darkened. Wings (fig. 19) light yellow, the radial field beyond the cord more brownish; a restricted but conspicuous dark brown dotted and spotted pattern, including small marginal spots on all the veins, largest on the anal veins; larger areas at origin of Rs, along cord and outer end of cell 1st M_2, and at fork of M_{1+2}; outer ends of radial cells with conspicuous pale yellow areas; veins yellowish, brown in the infuscated areas. Axillary crenulation larger and more conspicuous than in *subcrenulata,* but shallower and more elongate than in *crenulata.* Venation: Supernumerary crossveins and spurs in cell C relatively few, not exceeding seven; Rs longer; cell R_3 deeper; m-cu at or very close to the fork of M.

Abdominal tergites yellowish brown, caudal margins narrowly darker, the outer segments more uniform brown; sternites obscure yellow.

LUZON, Mountain Province, Benguet, Pauai, altitude about 8,000 feet, April 11, 1930 (*Rivera*) ; holotype, female.

Of the numerous allied species of *Epiphragma* in Luzon, *E. cinereinota* is closest to *E. crenulata* Alexander, differing most conspicuously in the larger size, structure of the antennæ, and the less-developed axillary crenulation of the wing.

LIMNOPHILA (LIMNOPHILA) BENGUETANA sp. nov.

General coloration brown; antennæ short; femora and tibiæ brown; wings cream-colored, heavily patterned with brown, including a series of about six major costal areas; R_2 very faint to subobsolete; m-cu at midlength of cell 1st M_2; male hypopygium with the outer dististyle terminating in a simple acute spine.

Male.—Length, about 5 millimeters; wing, 6.2.

Rostrum and palpi black. Antennæ brownish black throughout, short, if bent backward not extending far beyond the pronotum. Head brownish gray.

Mesonotal præscutum with the interspaces sparsely brownish yellow pollinose, the usual three stripes darker brown, the lat-

eral stripes crossing the suture and including the scutal lobes; median region of scutum and the scutellum more yellowish testaceous; postnotum grayish brown. Pleura with the dorsal sclerites darkened, the sternopleurite and meron more yellowish. Halteres yellow. Legs with the coxæ brownish yellow; trochanters obscure yellow; femora and tibiæ light brown, the tips of the latter slightly darkened; tarsi brownish black; legs with relatively conspicuous setæ. Wings (fig. 20) with the ground color cream-colored, heavily but rather restrictedly patterned with brown, the areas arranged much as in species of *Ephelia,* there being a heavier costal pattern of about six areas, the first at arculus, the third and fourth confluent into a U-shaped figure that encircles a pale spot beyond vein Sc; paler brownish gray areas at ends of longitudinal veins and as clouds in cells M, Cu, R_5, and the anal cells; veins pale, a very little darker in the clouded areas. Macrotrichia of veins small, restricted to veins beyond cord, except on R_1. Venation: Sc_2 near tip of Sc_1; Rs long, arcuated at origin, in alignment with R_{2+3+4}; R_2 very faint to subobsolete, its apparent location as figured; veins R_3 and R_4 divergent; cell M_1 present but small; m-cu at mid-length of cell 1st M_2; anterior arculus poorly indicated or lacking.

Abdomen more or less bicolored, especially the sternites, the segments obscure yellow, margined caudally by dark brown; hypopygium chiefly dark-colored. Male hypopygium (fig. 56) with the outer dististyle, *od,* simple, curved to the simple acute tip, the basal portion with conspicuous setæ. Inner dististyle, *id,* with the tip obtusely rounded. Interbasal process blackened, the apex expanded into a head. Gonapophyses, *g,* appearing as simple chitinized blades. Ædeagus, *a,* short.

LUZON, Mountain Province, Benguet, Pauai, altitude about 8,000 feet, April 20, 1930 (*Rivera*); holotype, male.

Limnophila benguetana is most closely allied to *L. guttularis* Edwards (Borneo), differing in the darkened legs and details of wing pattern and venation. The species has a wing pattern that is virtually the same as that of many Holarctic and Oriental species of the subgenus *Ephelia.* The apparent loss of the anterior arculus and the structure of the male hypopygium are characters strongly suggestive of *Pseudolimnophila,* but the venation is quite typical of *Limnophila.* Edwards has considered that his *guttularis* is a member of the typical subgenus

of *Limnophila* (*Poecilostola* Schiner, syn.) despite the very different general appearance of the species from the genotype of *Limnophila* (*pictipennis* Westwood).

LIMNOPHILA (DICRANOPHRAGMA) PARDALOTA sp. nov.

General coloration of mesonotum yellowish brown; knobs of halteres infuscated; legs yellow; wings relatively narrow, cream-colored, with an abundant dotted and spotted pattern, the areas more elongate and generally parallel in cells M and Cu.

Female.—Length, about 7.5 millimeters; wing, 6.5.

Rostrum and palpi black. Antennæ with the scapal segments black, the flagellum reddish brown, the outer segments darker. Head yellowish brown.

Mesonotal præscutum yellowish brown, the median region a little darker; posterior sclerites of mesonotum a little more pruinose. Pleura dark brownish gray. Halteres pale yellow, the apices of the knobs infuscated. Legs with the fore coxæ dark brown, the remaining coxæ and trochanters yellow; remainder of legs yellow, the terminal tarsal segments dark brown. Wings (fig. 21) relatively narrow, cream-colored, with a very abundant dotted and spotted brown pattern, the major groups lying above the origin of Rs and in the stigmal region; the dots are grouped in all the cells, in cells M and Cu becoming more transversely lengthened and regularly spaced to appear as parallel bands at the ends of the medial, cubital, and anal veins, the areas grouping to form more or less distinct circles; veins yellow, a little darker in the infuscated areas. Venation: Supernumerary crossvein in cell R_3 at near two-thirds the length of the cell; cell M_1 small; m-cu at near one-third the length of the small cell 1st M_2.

Abdominal tergites dark brown, the sternites more reddish brown, the caudal margins of the segments dark brown. Ovipositor with the shields reddish brown, the elongate valves brownish horn color.

LUZON, Mountain Province, Benguet, Mount Santo Tomas, above Baguio, altitude over 5,000 feet, October 9, 1929 (*Duyag*); holotype, female.

Limnophila pardalota is distinct from all of the numerous species of *Dicranophragma* now known from eastern Asia. The narrow wings with an unusually abundant dotting gives to the fly a conspicuous appearance.

ERIOPTERINI

TOXORHINA (TOXORHINA) MONTINA sp. nov.

General coloration brownish gray; head and posterior sclerites of mesonotum light gray; præscutum with three dark brown stripes; pleura pale, darker dorsally; wings grayish; abdominal tergites darkened; hypopygium black, the tergite deeply emarginate medially, forming long glabrous earlike lobes.

Male.—Length, excluding rostrum, about 4.5 to 5 millimeters; wing, 5.5 to 5.6; rostrum, about 5.

Female.—Length, excluding rostrum, about 7 to 7.5 millimeters; wing, 6 to 6.2; rostrum, about 5.5.

Rostrum elongate, black. Antennæ with the scapal segments yellow, especially the second segment; flagellum black. Head light gray.

Mesonotal præscutum reddish brown, with three dark brown stripes that become confluent posteriorly, or nearly so; humeral region more or less yellowish gray pruinose; scutal lobes dark brown; scutellum and postnotum gray. Pleura chiefly pale, the anepisternum darkened. Halteres dark brown, the base of stem narrowly yellow. Legs with the coxæ and trochanters yellow, the fore coxæ more infuscated; remainder of legs black, the bases of femora restrictedly pale. Wings with a grayish tinge, iridescent; veins black, those of basal half sometimes pale. Venation: Sc_1 ending opposite the origin of Rs, Sc_2 some distance from its tip; m-cu close to fork of M.

Abdominal tergites dark reddish brown, the margins blackened; sternites paler, especially of the basal segments; hypopygium black. Male hypopygium much as in *duyagi*, differing especially in the structure of the tergite, the latter with the caudal margin deeply emarginate, the conspicuous earlike lateral lobes entirely glabrous. In *duyagi*, the median region of the tergite is only slightly notched, the entire margin set with dense short setæ.

LUZON, Mountain Province, Benguet, Mount Santo Tomas, above Baguio, altitude over 5,000 feet, October 9, 1929 (*Duyag*); holotype, male; allotype, female; paratypes, 4 males and females.

Toxorhina montina is very like *T. duyagi* Alexander, but the structure of the ninth tergite of the male hypopygium is amply distinct.

TOXORHINA (TOXORHINA) BICEPS sp. nov.

General coloration yellow, the mesonotum variegated with brown; pleura yellow, unmarked; rostrum longer than the body; wings tinged with dusky; cell 1st M_2 open by the atrophy of m; male hypopygium with the outer dististyle bifid at apex.

Male.—Length, excluding rostrum, about 5.5 millimeters; wing, 6; rostrum, about 6.5.

Rostrum black, longer than the body. Antennæ with the basal segment brown; second segment light yellow; flagellum black. Head gray, the center of the vertex darkened; no corniculus.

Mesonotal præscutum yellow, with three brown stripes, the median stripe becoming obsolete at near midlength of the sclerite, on its anterior portion becoming more or less confluent with the lateral stripes; scutal lobes brownish black; scutellum black; postnotal mediotergite gray. Pleura clear light yellow. Halteres dark brown, the stem somewhat paler, its extreme base yellow. Legs with the coxæ pale yellow; trochanters more whitish; remainder of legs black, only the femoral bases very restrictedly brightened. Wings (fig. 22) with a strong dusky tinge, somewhat more intense in cell M adjoining vein Cu; prearcular and costal regions slightly more yellowish; veins black, somewhat paler at the wing base. Macrotrichia on entire length of Rs and on all branches of M and Cu beyond the cord. Venation: Sc_1 ending just beyond origin of Rs; cell 1st M_2 open by the atrophy of m; m-cu a short distance before the fork of M.

Abdominal tergites dark brown, the sternites light yellow; ninth segment light yellow, the basistyles again dark brown. Male hypopygium (fig. 57) with the outer dististyle, *od*, small, at apex with two slender blunt arms that form about a straight angle. Inner dististyle, *id*, longer, arcuate, at near midlength on outer margin with a small pale flange. Arms of ædeagus, *a*, short and stout.

LUZON, Mountain Province, Benguet, Mount Santo Tomas, above Baguio, altitude over 5,000 feet, March 21, 1930 (*Rivera*); holotype, male.

Toxorhina biceps is very different from *T. duyagi* Alexander and *T. montina* sp. nov. in the structure of the male hypopygium, notably of the outer dististyle.

ERIOPTERA (ERIOPTERA) RUBRIPES sp. nov.

General coloration yellowish brown, the præscutum with three brown stripes; head black, the broad orbits light gray; pleura obscure yellow, variegated with darker; knobs of halteres brownish black; legs reddish yellow, only the terminal tarsal segments darkened; wings with a strong grayish yellow suffusion, the costal cell whitish, the prearcular and remainder of costal region yellowish.

Female.—Length, about 5.5 to 6 millimeters; wing, 6 to 6.2.

Rostrum and basal segments of palpi obscure yellow, the terminal segments of the latter blackened. Antennæ brown, of rather unusual length for the female sex; flagellar segments long-oval to subcylindrical. Head black, the front and broad orbits light gray.

Mesonotal præscutum and scutum yellowish brown, the former with the three usual stripes darker, the scutal lobes similarly infumed; pseudosutural foveæ pale; scutellum brown, broadly margined behind with obscure yellow; postnotal mediotergite light brown, the cephalic portion darker with a more or less distinct yellow spot on sides. Pleura obscure yellow, the fore coxæ and a spot on dorsal portion of anepisternum dark brown; hypopleura and pleurotergite variegated paler brown and yellow, with a distinct bluish cast; sternum and meron clear light yellow. Halteres pale, the knobs brownish black. Legs with the coxæ yellow, more or less pruinose and darkened, especially the fore coxæ, as described; trochanters yellow; remainder of legs reddish yellow, the terminal tarsal segments darkened. Wings with a strong grayish yellow suffusion, the prearcular and costal regions clearer yellow; cell C almost white; certain of the veins, as R_5 and Cu_1 narrowly bordered by light yellow; veins pale to yellow, the long macrotrichia brown or black. Venation: R_{2+3+4} a little longer than the basal section of R_5; M_4 and Cu_1 deflected strongly cephalad at outer ends; vein 2d A strongly sinuous, as in the subgenus.

Abdominal tergites dark brown, the caudal margins of the outer segments narrowly yellow, on the genital segment including the entire sclerite; sternites dark, the outer segments margined caudally and more restrictedly laterally with yellow. Ovipositor with the slender smooth valves horn-yellow.

LUZON, Mountain Province, Benguet, Mount Santo Tomas, above Baguio, altitude over 5,000 feet, March 21, 1930 (*Rivera*); holotype, female; La Trinidad, below Baguio, in open parklike area, altitude about 4,800 feet, April 20, 1930 (*Rivera*); paratype, female; Laguna Province, near Ube, in boggy area, March 4, 1930 (*McGregor*); paratype, female.

Erioptera (*Erioptera*) *rubripes* is amply distinct from similar large regional species in the combination of wing coloration, blackened knobs of halteres, and unvariegated legs.

ILLUSTRATIONS

[Legend: *a*, ædeagus; *b*, basistyle; *dd*, dorsal dististyle; *g*, gonapophysis; *id*, inner dististyle; *od*, outer dististyle; *t*, tergite; *vd*, ventral dististyle.]

PLATE 1

FIG. 1. *Tipulodina pampangensis* sp. nov., wing.
2. *Scamboneura subtransversa* sp. nov., wing.
3. *Scamboneura primogenia* sp. nov., wing.
4. *Scamboneura banahaoensis* sp. nov., wing.
5. *Macgregoromyia brevisector* sp. nov., wing.
6. *Limonia* (*Limonia*) *ligayai* sp. nov., wing.
7. *Limonia* (*Libnotes*) *neofamiliaris* sp. nov., wing.
8. *Limonia* (*Libnotes*) *subfamiliaris* sp. nov., wing.
9. *Limonia* (*Libnotes*) *perparvula* sp. nov., wing.
10. *Limonia* (*Libnotes*) *elata* sp. nov., wing.
11. *Limonia* (*Dicranomyia*) *benguetensis* sp. nov., wing.
12. *Limonia* (*Geranomyia*) *bifidaria* sp. nov., wing.
13. *Limonia* (*Geranomyia*) *pleuropalloris* sp. nov., wing.
14. *Limonia* (*Doaneomyia*) *pampangensis* sp. nov., wing.
15. *Limonia* (*Thrypticomyia*) *octosetosa* sp. nov., wing.
16. *Helius* (*Eurhamphidia*) *diacanthus* sp. nov., wing.
17. *Adelphomyia luzonensis* sp. nov., wing.
18. *Epiphragma subcrenulata* sp. nov., wing.
19. *Epiphragma cinereinota* sp. nov., wing.
20. *Limnophila* (*Limnophila*) *benguetana* sp. nov., wing.
21. *Limnophila* (*Dicranophragma*) *pardalota* sp. nov., wing.
22. *Toxorhina* (*Toxorhina*) *biceps* sp. nov., wing.

PLATE 2

FIG. 23. *Scamboneura subtransversa* sp. nov., male hypopygium, ninth tergite.
24. *Scamboneura subtransversa* sp. nov., male hypopygium, inner dististyle.
25. *Scamboneura subtransversa* sp. nov., male hypopygium, appendage of ninth sternite.
26. *Scamboneura subtransversa* sp. nov., male hypopygium, margin of eighth sternite.
27. *Scamboneura primogenia* sp. nov., male hypopygium, ninth tergite.
28. *Scamboneura primogenia* sp. nov., male hypopygium, dististyles.
29. *Scamboneura primogenia* sp. nov., male hypopygium, appendage of ninth sternite.
30. *Scamboneura primogenia* sp. nov., male hypopygium, gonapophysis.
31. *Scamboneura banahaoensis* sp. nov., male hypopygium, ninth tergite.

FIG. 32. *Scamboneura banahaoensis* sp. nov., male hypopygium, outer dististyle.
33. *Scamboneura banahaoensis* sp. nov., male hypopygium, inner dististyle.
34. *Scamboneura banahaoensis* sp. nov., male hypopygium, appendage of ninth sternite.
35. *Scamboneura plumbea* Alexander, male hypopygium, ninth tergite.
36. *Scamboneura plumbea* Alexander, male hypopygium, outer dististyle.
37. *Scamboneura plumbea* Alexander, male hypopygium, inner dististyle.
38. *Scamboneura plumbea* Alexander, male hypopygium, appendage of ninth sternite.
39. *Scamboneura unicolor* Bezzi, male hypopygium, ninth tergite.
40. *Scamboneura unicolor* Bezzi, male hypopygium, outer dististyle.
41. *Scamboneura unicolor* Bezzi, male hypopygium, inner dististyle.
42. *Scamboneura unicolor* Bezzi, male hypopygium, appendage of ninth sternite.

PLATE 3

FIG. 43. *Dolichopeza* (*Nesopeza*) *haightensis* sp. nov., male hypopygium.
44. *Macgregoromyia brevisector* sp. nov., male hypopygium, ninth tergite.
45. *Macgregoromyia brevisector* sp. nov., male hypopygium, outer dististyle.
46. *Macgregoromyia brevisector* sp. nov., male hypopygium, inner dististyle.
47. *Limonia* (*Limonia*) *ligayai* sp. nov., male hypopygium.
48. *Limonia* (*Libnotes*) *neofamiliaris* sp. nov., male hypopygium.
49. *Limonia* (*Libnotes*) *perparvula* sp. nov., male hypopygium.
50. *Limonia* (*Libnotes*) *elata* sp. nov., male hypopygium.
51. *Limonia* (*Dicranomyia*) *benguetensis* sp. nov., male hypopygium.
52. *Limonia* (*Geranomyia*) *bifidaria* sp. nov., male hypopygium.
53. *Limonia* (*Thrypticomyia*) *octosetosa* sp. nov., male hypopygium.
54. *Helius* (*Eurhamphidia*) *diacanthus* sp. nov., male hypopygium.
55. *Helius* (*Eurhamphidia*) *abnormalis* (Brunetti), male hypopygium, apex of outer dististyle and gonapophysis.
56. *Limnophila* (*Limnophila*) *benguetana* sp. nov., male hypopygium.
57. *Toxorhina* (*Toxorhina*) *biceps* sp. nov., male hypopygium.

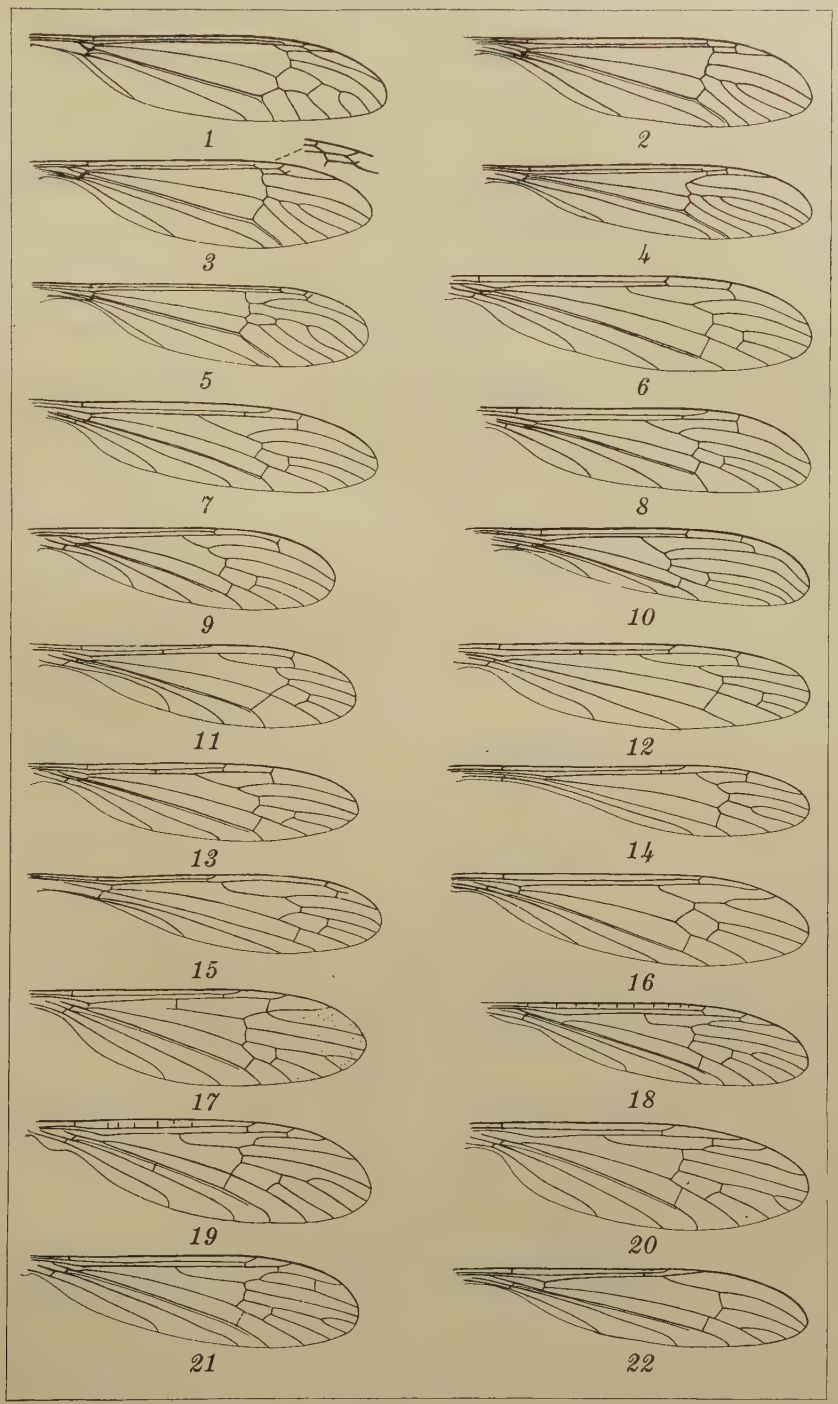

PLATE 1.

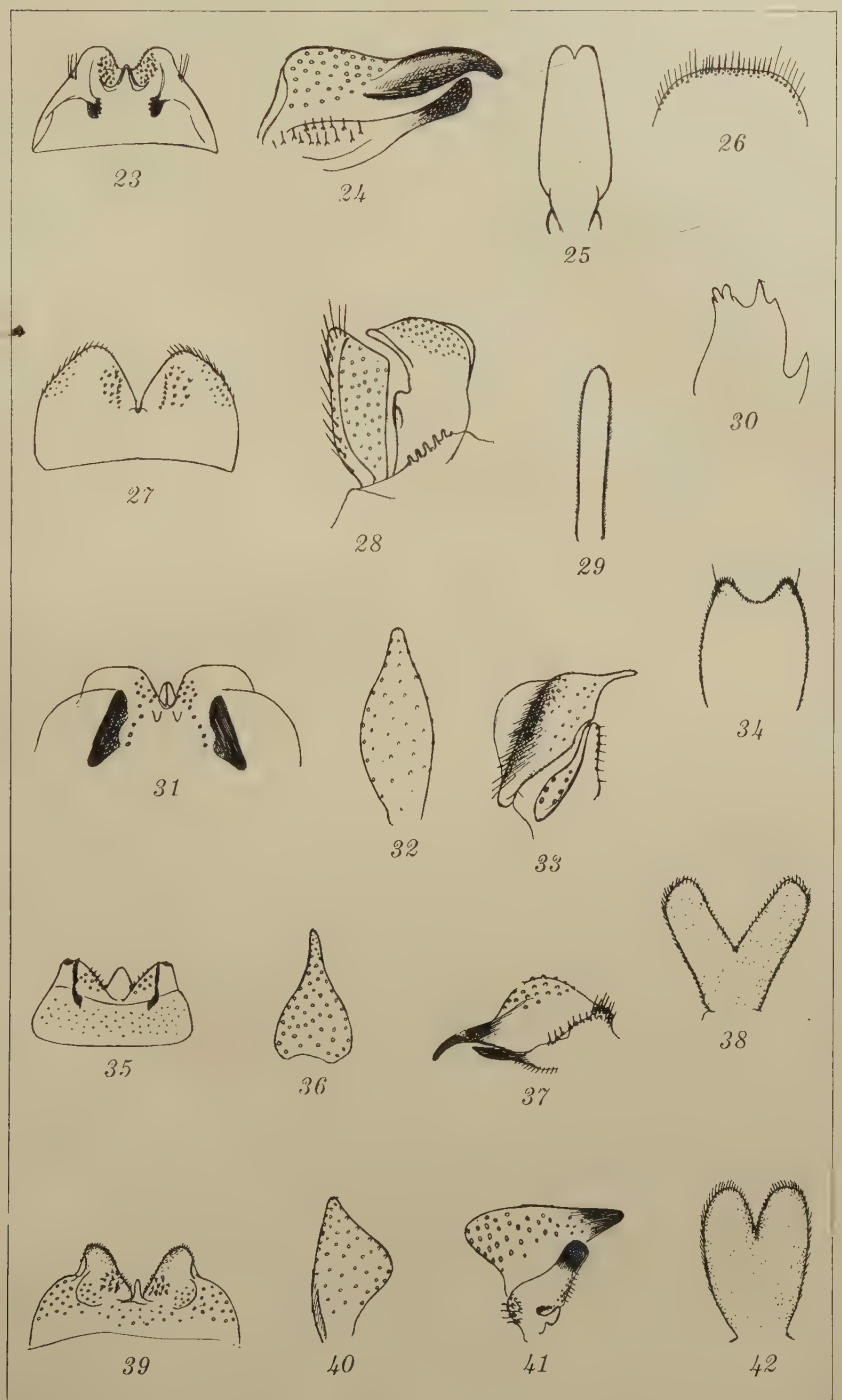

PLATE 2.

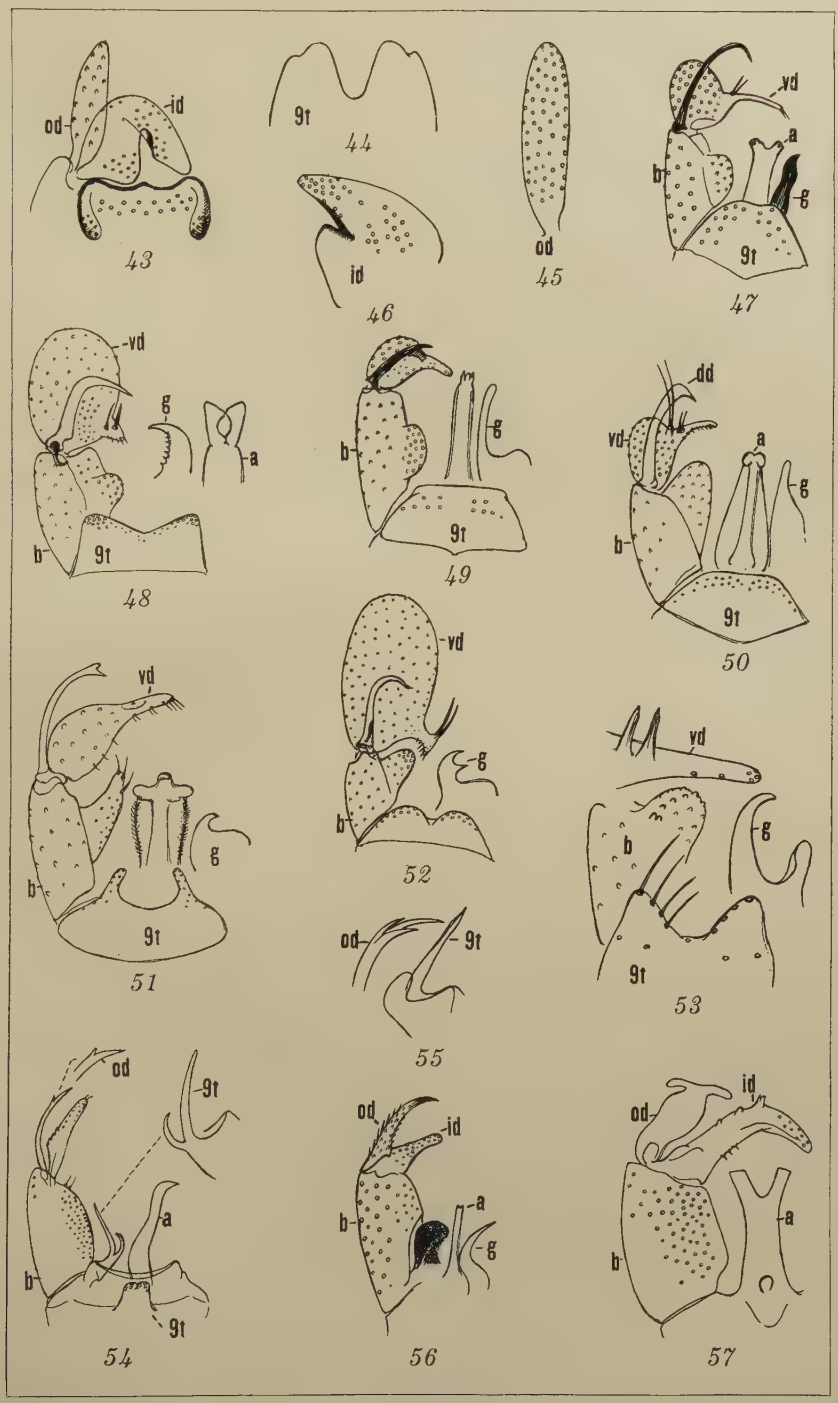
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PLATE 3.

STUDIES ON INFANTILE BERIBERI BASED ON FIVE HUNDRED FOURTEEN CASES

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ONE TEXT FIGURE

RETROSPECT

RAVAGES OF THE DISEASE

On account of its ravages, infantile beriberi, or the beriberi affecting infants who are nursed by beriberic mothers, is without doubt the most important infant disease to the Filipino practitioner. Three years ago, the Philippine Committee on Beriberi(1) stated that infantile beriberi claimed an average of 16,500 deaths annually among infants alone, representing 28.10 per cent of the total deaths among infants under 1 year of age. In 1910, I ventured to state that while the mortality among breast-fed infants in the Philippines was 65 per cent, in Germany it was only 9 per cent.(2) The reason for this was the great toll caused by infantile beriberi. In view of this singular fact, unparalleled in the history of medicine, human milk as a food appears to be a scourge to the Filipino infant, an inverse phenomenon to the experience of other nations, where human milk is the strongest bulwark of child hygiene, the "magic liquor" that guarantees the life of the infant.

It should be noted that so long as we consider this disease as adult beriberi in miniature, we shall be committing a gross mistake. Infantile beriberi differs from adult beriberi in almost every particular; pathological, clinical, and therapeutical. The multiple neuritis observed in adults is unknown in infants. The clinical manifestations in them are very peculiar and characteristic. With regard to the effects of specific therapy, tikitiki extract has a wonderful effect on infants but is valueless to adults.

HIROTA'S DISCOVERY

Although beriberi as a disease existed from remote antiquity and was known to the Romans as early as 24 B. C., the knowl-

edge was confined to the adult form. Eminent European and Japanese physicians, experts in tropical medicine, were not aware of the existence of infantile beriberi. Baelz claimed to have observed it in children only during the second dentition; that is, at about 6 years of age, and Scheube,(3) in his classical book published in 1900, said that the youngest patient he had treated was a child of 8 years. Clark,(4) of Hongkong, writing in the same year of an epidemic of beriberi in the Berlin Foundling Home of that place, mentioned the occurrence of beriberi among children 4 years old.

The closing years of the 19th century were memorable in the annals of medicine in the Tropics, for then Hirota,(5) of Tokyo, revealed to the world his transcendental observations on a disease that affected only breast-fed children and hastened the dawn of our knowledge concerning this obscure malady, which he called infantile beriberi. As early as January, 1888, this great Japanese scientist observed in some infants that were brought to his clinic peculiar and strikingly interesting symptoms upon which he based his epoch-making studies. Notable among them were obstinate vomiting, change of humor, incessant crying, constant whining, dyspnœa, œdema, aphonia, diminished amount of urine, accelerated but clear heart beats, slightly coated tongue, negative albumin in the urine, and negative lung findings. He then began to gather cases as they came to his clinic, and after collecting about thirty presented the results of his studies in a meeting of the General Association of the Medical Society of Tokyo, in April, 1891.

His interest did not end there, and from that simple, yet significant beginning, he pursued a more extensive and intensive investigation, and in December, 1897,(6) reported fifty-two additional cases consisting of thirty-eight males and fourteen females, whose ages varied from 1 to 13 months. Forty-two of these cases were reported as completely cured, five died, and five were of unknown termination.

In the course of this study he noticed two further interesting peculiarities of the disease. First, that the children were nursed by mothers or wet nurses who exhibited symptoms of adult beriberi; that is, paræsthesis on the feet and finger tips, chest oppression, and constipation. Second, that no medicine was able to effect a cure, in spite of a number of remedies that he tried. In view of these facts, he thought that possibly it was the mother's milk that was at fault, and consequently substituted artificial feeding for breast feeding with which he obtained

gratifying results. With the exception of the aphonia, which lasted for several weeks, the symptoms disappeared with considerable rapidity. The humor improved, vomiting ceased in one or two days, and complete cure was effected within three days. Because of these striking results, he was tempted to conclude that infantile beriberi was an intoxication produced by the milk of beriberic mothers, and that suppression of maternal feeding was the only effective, rational, and causal method of treatment.

However, since the majority of his cases were obtained from out-patients who were being treated in his clinic, his observations were rather incomplete. It was only during the latter part of 1897 (August to November) that he had the chance to observe four patients who were admitted and treated in the hospital ward, the youngest being an infant 1.5 months old, in whom he observed the absence of any motor or sensory disturbances. This important observation enabled him to formulate his classical table comparing the symptomatology of infantile beriberi with the acute cardiac form of adult beriberi. Because of the clear description and masterly presentation of his cases, and the publication of his table in a German medical journal, it soon began to attract world-wide attention.

BERIBERI IN THE PHILIPPINE ISLANDS

Bantug,(7) in his report on mortality statistics in the Census of the Philippine Islands, 1918, volume 2, cites the earliest mention of the disease in Philippine literature. He says, in part:

> In describing the Malay Archipelago, Father Colin(8) speaks of beriberi in no uncertain terms. The following, written about 1658, attests to his familiarity with the disease with which he must have become acquainted during his long years of missionary labor in the Philippine Islands. The quotation is given in full:
>
> "The southeast wind is sickly because it comes over the volcanoes of Maquien, Mutiel, and Tidore at the season when the cloves are in bloom and the nutmeg is maturing, and its heat and dryness give rise to many diseases. Particularly the one called Berber, which in some affects the body and extremities, causing the same to swell and paralyzing all the joints, and when this swelling reaches the breast and touches the heart, those who have it die suddenly. In others this disease assumes a dry form, causing the body to dry up and wither from the waist down, until it consumes and kills the patient. The disease is dangerous and practically incurable."
>
> The first epidemic, however, recorded as occurring in the Philippine Islands was that described by Koniger, in 1882. His account is briefly summarized by Herzog(9) in his Studies in Beriberi.

PHILIPPINE MEDICAL LORE: EPIFANIO DE LOS SANTOS'S MEMORANDUM

In the Philippines, the existence of the disease had been recognized by native herb doctors under the name of *taong*, or *suba*, as early as the middle of the 17th century. According to a memorandum written especially at my request by the well-known historiographer Epifanio de los Santos, in February, 1910, the word "taong," or "suba," was already included in the Vocabulario de la Lengua Tagala published in 1574 by Fathers Noceda and Sanlucar(10) and the meaning given to it was, "blood rising up into the heart." The same topic was also treated by the Dominican friar Fr. Fernando Santa Maria(11) in his popular book, Manual de Medicinas Caseras, which was published in 1768.

The widespread knowledge of this disease is in evidence in the various names and diverse remedies that the natives applied to it; for example, Tagalogs, *taong*, or *taol*, or *suba;* Ilocanos, *til-i;* Pangasinanes, *subi-subi;* Cebuanos, *alferecia;* Pampangos, *taong;* Negros, *masosuelo;* Cagayanes, *til-i* among the Ilocano elements and *alferecia* among the Ibanag inhabitants.

Of the curious and extravagant remedies, the following enjoyed extraordinary popularity. The juice of *ampalaya* or *amargoso* [1] mixed with sugar or honey is to be given to the child immediately after birth until the mother is able to nurse her baby. This they did in order to expel the "bad blood," which they believed the child had sucked in utero. When the infant was attacked by taong, as when it cried unexpectedly, they administered any one of the following remedies: (*a*) Powdered malaube,[2] (*b*) excreta of cockroach, (*c*) boa's bile, (*d*) *gasparanton,* (*e*) *sapagkit,* (*f*) powdered pearl. These are diluted or mixed with a teaspoonful of the mother's milk. All of these remedies as well as the term "taong" have been carefully preserved as a legacy from generation to generation, and in many secluded barrios such medications are still in vogue.

Til-i was treated, among Ilocanos, by the bile of a chicken, of a lizard, commonly called *bañas,* or of a boa, known as *betlat* among them. They have the custom of preserving the gall bladder, when they kill a chicken, lizard, or boa, by hanging it in a conspicuous place on the wall of the kitchen; usually, the wall facing the stove. They believed that the bile of boa, lizard, or chicken was curative for til-i.

[1] *Momordica charantia* Linn.
[2] *Aristolochia tagala* Cham.

STUDIES DURING THE SPANISH RÉGIME

During the latter part of the Spanish régime the Excelentisimo Ayuntamiento de la Ciudad de Manila, in its efforts to investigate the cause of the excessively high infant-mortality rate and the amazingly great number of children dying from "taong," in a session held December 14, 1886, approved the holding of a symposium among the members of the "beneficiencia Municipal," on the subject, "Ecclampsia, causes which produce the excessive number of infants dying of this disease and means to diminish this mortality." Of the works presented by the seven physicians who participated in it, that of Dr. Manuel Xeres Burgos(12) was considered the best.

Like the rest of the practitioners at the time, Dr. Xeres Burgos considered "taong" as synonymous with "ecclampsia" and "infantile convulsions" and ascribed the high number of children suffering and dying from it to four causes; namely, (*a*) ignorance of the parents, (*b*) absence of any notion about hygiene, (*c*) charlatanism of the quacks, and (*d*) the custom of not calling a physician until the infants were dying.

Years later, another Filipino doctor, Manuel Gomez y Martinez,(13) writing on the same subject, concluded that "taong" was nothing more than a mere nervous exhaustion due to gastralgia and intestinal colic produced by digestive disturbances occasioned by faulty feeding.

In spite of all these researches to elucidate the nature of the puzzling problem we remained groping in obscurity and confusion, for until 1904 the Filipino practitioners, with whom I had the opportunity to be in intimate relationship, Manuel Madrigal, Felipe Zamora, and others, still considered "taong" as "infantile convulsions." Even in those days we already noticed cases with aphonia followed by death and loud incessant crying ending fatally; but we did not ascertain its veritable nature, and in our private, confidential conversations we considered the former sometimes as cardiac failure, bronchitis, or pneumonia, and the latter as a form of acute peritonitis.

THE FIRST LINK; GUERRERO'S CLINICAL STUDIES

Then the happy moment arrived that will make the year 1904 a memorable date in the evolution of the medical sciences in the Philippines and one which will recall to memory, whenever the subject of "infant mortality" is touched upon, the name of one of the luminaries of Philippine medicine and to whom the whole country is indebted, Dr. Manuel Guerrero.(14) To him

belongs the honor of having made the first and most acceptable theory on the subject of "taong," for on October 10 of that year, in a meeting of the Colegio Medico-Farmaceutico in Manila, he presented a memoir in which he identified our "taong" with Hirota's infantile beriberi. How he came to this blessed conclusion is vividly narrated in the introductory remarks to a monograph which he and Quintos published in 1910, where he partly said—

> . . . obsessed by our excessive infant mortality, and unable to recognize or identify the legitimate nature of the disease which causes it, since its symptomatology did not fit any clinical picture hitherto described in the European infantile pathology, reading an article of Hirota about a disease on breast-fed infants produced by the milk of beriberic mothers, and seeing that the clinical picture of that disease portrayed by the said professor, counterfeits in full our "taong," convinced us that this disease, which until then was vaguely understood in the Philippines, was the beriberi of breast-fed infants observed by Hirota.

Guerrero's article accomplished four important things—first, it established the first basic symptomatic link; second, it produced a complete revolution of our ideas concerning "taong;" third, it paved the way for a new orientation in the study of this malady, and lastly, it renewed our interest in the mystery of this disease.

THE SECOND LINK: ALBERT, MARSHALL AND GILMAN, McLAUGHLIN AND ANDREWS'S NECROPSIES

Since that time the native doctors began to familiarize themselves with the clinical symptoms of infantile beriberi, and December 4, 1908, the diagnosis of a typical case of infantile beriberi of the cardiac type in a child 3 months old, was corroborated on the necropsy table by the late Harry Marshall and P. K. Gilman;(15) who, besides demonstrating the typical anatomical lesions as already pointed out by M. Miura,(16) of Japan, in 1897, showed further the presence of a degenerative neuritis of the vagus, a further step in our knowledge of this disease, and established its pathological entity. This was the second important link.

Subsequent to this, in the latter part of 1909, the Bureau of Health attempted to confirm by biopsy the clinical diagnosis appearing on the death certificates of infants under 1 year of age dying in Manila. McLaughlin and Andrews,(17) in their Studies on Infant Mortality, carefully analyzed the pathological findings in a series of 219 infants dying under 1 year, and demonstrated that of this number, 124, or 56.6 per cent, died of

a condition "which for want of a better term" they designated "moist beriberi."

SKEPTICISM: THE FIRST MEETING OF THE FAR EASTERN ASSOCIATION OF TROPICAL MEDICINE

Glimpses of the discussion of this paper by McLaughlin and Andrews in the First Biennial Meeting of the Far Eastern Association of Tropical Medicine revealed the skepticism of several prominent members of the delegation present in accepting the conclusion that possibly "taong," or infantile beriberi, was responsible for our high infant mortality. Doctor Musgrave did not believe that infantile beriberi was identical with "taong" and recommended that such a term be held in abeyance; at least, until such time as the etiologic agent and the clinical picture are made more definite. Doctor Clark, of Hongkong, also thought it was premature to term the pathological entity "infantile beriberi" and regarded our "taong," as nutritional in nature, in which Dr. Antonio Sison concurred. Dr. Hans Aron claimed that it is similar to Czerny's Mehlnarschaden or carbohydrate intoxication.

GUERRERO AND QUINTOS'S AND ANDREWS'S MONOGRAPHS

In the meantime Guerrero and Quintos,(18) to complete and to corroborate further their memoir of 1904, studied additional cases, which culminated in the presentation of a monograph published in Manila in 1910 with the title, El Beriberi en los Niños de Pecho. The study comprised one hundred seventy-two cases with two autopsies performed twenty-two and thirty-two hours after death, respectively. In this work the authors discussed completely and in a masterly way the clinical and anatomical manifestations of the disease as well as the various therapeutic agents that filled the physician's armamentarium at that period. Furthermore, they reaffirmed Hirota's view that infantile beriberi is the result of an intoxication produced by the milk of beriberic mothers, and that the best method of treatment is the suppression of breast feeding.

Andrews,(19) in 1912, working independently, studied the manifestations of beriberi in both the mother and the infant, followed immediately by necropsy. He based his diagnosis of infantile beriberi on four points; namely, (*a*) cardiac dilatation and hypertrophy, (*b*) congestion of the viscera, (*c*) anasarca, and (*d*) absence of any other findings to account for the death.

In his conclusions, Andrews believed that infantile beriberi was due neither to bacteria in the milk nor to an infection or

toxæmia of either the mother or the child, "but to something lacking in the mother's milk which is essential for the growth of the nerves of the child." Working on this hypothesis he attempted to reproduce the disease by feeding puppies with the milk of mothers whose children died of beriberi, and claimed to have succeeded in reproducing the disease in these animals.

THE THIRD LINK: CHAMBERLAIN AND VEDDER'S TIKITIKI EXTRACT

While the works of Van Leent, Fraser and Stanton, Strong and Crowell, Eijkman, Funk, Andrews, and others pointed to the deficiency nature of the disease, it remained for Chamberlain and Vedder(20) to give the last and decisive proof against the old "intoxication" theory of its etiology. It should be stated that previous to Chamberlain and Vedder's studies, native physicians, influenced by the works of the above-mentioned authorities, treated their beriberi patients by administering large quantities of rice polishings to the mother and weaning the child at the same time, a method open to many serious objections; among them, (*a*) it unnecessarily subjects the infants to all the dangers that attend artificial feeding; (*b*) the difficulty of providing proper canned or fresh milk, as the majority of these cases were of the very poor class; (*c*) no conclusion can be arrived at, since weaning alone produces a cure, as was first shown by Hirota; and (*d*) it is difficult to administer rice polishings because of its unpleasant taste, and it is absolutely impossible to feed it to infants.

Chamberlain and Vedder, convinced that beriberi was due to a deficiency and not to an intoxication, thought that the suspension of lactation was unnecessary, provided that the missing substance can be supplied artificially. In accordance with this belief they determined to treat cases of infantile beriberi by administering the extract of rice polishings directly to the infant while permitting it to continue nursing its mother.

The infants were all given twenty drops of the extracts of rice polishings every two hours while awake, until 5 cubic centimeters was consumed in twenty-four hours, which is equivalent to 82 grams of rice polishings. The results have been truly marvelous. Improvement was immediate. Vomiting stopped in twenty-four to thirty-six hours. The dyspnœa and palpitation ceased after two or three days; urination became normal; the aphonia, however, did not disappear until after about two months of treatment.

Inspired by these excellent results, they said that this extract is a "cure" in the true sense of the word, just as lime

juice is a "cure" for scurvy, and that it acts with as great promptitude as does fruit juice in infantile scorbutus. They regarded their work with infantile beriberi as the final link in the chain of evidence that has been built up from experiments on men and animals, and which proves that an improper diet, usually one consisting mainly of highly milled rice, is responsible for the development of beriberi.

EXTENSIVE TRIAL OF TIKITIKI EXTRACT BY THE LIGA NACIONAL FILIPINA

Following this discovery, and on account of the high infant mortality, the Philippine Legislature appointed a committee to investigate and to adopt measures that would tend to diminish this rate. Early in 1914, this committee submitted its report wherein infantile beriberi was ranked first in importance in the mortality and morbidity of the Islands. In the same year, the Segunda Asamblea Regional de Médicos y Farmacéuticos de Filipinas presented a resolution to the Philippine Legislature which was converted into the Angeles Act approved February 28, 1914, appropriating a certain sum of money for the preparation and free distribution of tikitiki extract to the poorer classes. The preparation was entrusted to the Bureau of Science in Manila, and the Liga Nacional Filipina para Protección de la Primera Infancia was appointed custodian and distributor.

The island-wide campaign against this disease might be gleaned from the figures contained in the fifth report of the Liga Nacional, 1918,(21) and the heavy output of tikitiki extract from the private laboratories of Zamora, Hizon and Rodriguez, and others. From October 16, 1917, to October 15, 1918, the Bureau of Science alone supplied 8,019 bottles, 50 cubic centimeters each, and 150 ampules, 1 cubic centimeter each, of tikitiki extract, which were distributed free in various provinces and in the City of Manila. The results were commensurate with the money spent, for the percentage of deaths among infants was markedly reduced as may be seen in Table 1.

TABLE 1.—*Cases of infantile beriberi treated and percentage of deaths, 1914 to 1918.*

Years.	Cases treated.	Percentage of deaths.
1914 (June 15 to October 15)	72	15.2
1914 to 1915 (October 16 to October 15)	273	1.09
1915 to 1916 (October 16 to October 15)	272	1.4
1916 to 1917 (October 16 to October 15)	524	0.76
1917 to 1918 (October 16 to October 15)	350	0.79

It is not too alluring to say that such results fulfilled our prediction in 1916 that theoretically no child attacked by infantile beriberi should die if treated early and properly.

In 1918, after such an extensive trial and conclusive results, La Liga Nacional submitted its fifth report to the Legislature with this conclusion:

> For all that has been presented this body believes and thinks that the period of *trial and experimentation* in the treatment of infantile beriberi with the extract of tikitiki, can be said to have concluded, and that this remedy discovered in 1911 by the American doctors, Chamberlain and Vedder, administered in convenient doses is the drug most effective and sure which medicine counts on to-day to combat this terrible disease which pays a high toll of innocent breast-fed infants yearly in Manila and which is responsible for about 30 per cent of the infant mortality. In this respect it can be affirmed that the resolution presented by the "Segunda Asamblea Regional de Médicos y Farmacéuticos de Filipinas," converted into Angeles Bill . . . is one of the most beneficial laws and is of immense significance for the future of the Filipino people since that law tends to solve in part the problem of infant mortality and depopulation.

It is no vainglory to say that it was only extensive clinical observations and untiring efforts in experimentation that made possible the fitting of the three important links—symptomatic, pathological, and etiological—in the chain of study of this disease with such happy result. Twelve years after the experimentation by the Liga Nacional, with continuous trial and researches, we are reaping its bountiful harvest; namely, the reduction of our infant mortality to about one-half, and the diminishing incidence of beriberi to such an insignificant number that because of its rarity many physicians, especially the younger ones, are losing the clinical picture of this disease.

THE FOUR EVIDENCES: PHILIPPINE GENERAL HOSPITAL, PHILIPPINE HEALTH SERVICE, PUERICULTURE CENTERS, MEDICAL PRACTITIONERS

From a corner in the children's ward of the Philippine General Hospital we have silently observed the uninterrupted effects of this discovery; the slow but steady diminution in the number of infants suffering from infantile beriberi, a diminution which inspired us to write our article, "Is infantile beriberi disappearing?"(22) The figures in Table 2, from the pediatrics ward of the hospital, clearly demonstrate this marvelous result.

This observation of ours is confirmed by the figures obtained from the office of vital statistics of the Philippine Health Service which are given in Table 3.

TABLE 2.—*Total infantile beriberi and percentage in relation to total admission under one year and all ages, by years, in pediatrics ward, Philippine General Hospital, College of Medicine, University of the Philippines.*

Year	Total admissions of infantile beriberi.	Total admissions of under 1 year.	Percentage of infantile beriberi to total admissions under 1 year.	Total admissions of all ages.	Percentage of infantile beriberi to total admissions of all ages.
1914	51	328	12.50	547	9.32
1915	45	304	14.80	577	7.79
1916	52	336	15.47	591	8.79
1917	51	422	12.08	866	5.89
1918	40	403	9.92	1,127	3.55
1919	24	344	6.97	792	3.03
1920	37	441	8.39	1,091	3.39
1921	39	348	11.20	1,171	3.33
1922	37	440	8.40	1,030	3.59
1923	46	378	12.16	1,276	3.61
1924	19	540	3.51	1,369	1.39
1925	18	558	3.22	1,383	1.30
1926	9	640	1.40	1,408	0.64
1927	6	573	1.04	1,316	0.46
1928	6	582	1.03	1,344	0.45
1929	19	703	2.70	1,573	1.15
1930	15	823	1.82	1,712	0.88
Total	514	8,163	6.29	18,173	2.82

TABLE 3.—*Total births and deaths in relation to cases of and deaths from infantile beriberi, from the Philippine Health Service.*

Year.	Total births.	Total deaths under 1 year.	Infant-mortality rate per 1,000 births.	Death from infantile beriberi.	Death rate from infantile beriberi per 1,000 births.
1914	9,599	3,325	346.39	899	93.66
1915	8,850	3,511	396.72	1,058	119.55
1916	9,082	3,059	336.82	805	88.64
1917	8,883	2,447	275.47	384	43.23
1918	9,083	3,611	397.56	597	65.73
1919	10,029	2,256	224.95	354	35.30
1920	12,614	2,687	213.02	555	44.00
1921	12,261	2,871	234.16	722	58.89
1922	13,092	2,543	194.24	671	51.25
1923	14,598	2,804	192.08	739	50.62
1924	13,969	2,733	195.65	664	47.53
1925	15,046	2,513	167.02	616	40.94
1926	14,813	2,463	166.27	538	36.32
1927	15,386	2,313	150.33	280	18.20
1928	15,709	2,378	151.38	360	22.92
1929	16,098	2,762	171.57	553	34.35
1930	16,581	2,657	160.24	317	19.12

As may be clearly seen, while in 1914 the infant-mortality rate from all causes was 346.39, in 1930 this was reduced to 160.24, and the mortality rate from infantile beriberi, which was then about 93.66 in 1914, was reduced to 19.12 in 1930. The decline in these rates may be seen in the accompanying graph.

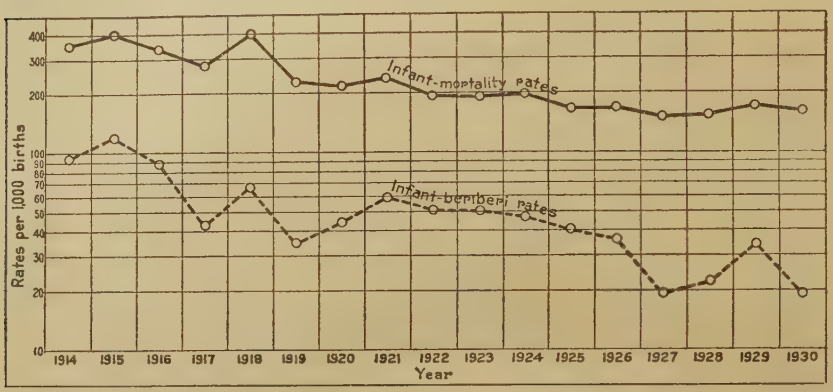

FIG. 1. Infant-mortality and infant-beriberi rates per 1,000 births (transients included) in the City of Manila by years.

The same phenomenon has been observed in the various puericulture centers that are strategically located in the different parts of the city as shown in the following statistics furnished by Dr. Tranquilino Elicaño.(23)

TABLE 4.—*Number of infants under 1 year in relation to number of beriberi cases admitted in different centers and number of bottles of tikitiki extract distributed.*

[Table from the office of the Public Welfare Commissioner.]

Year.	Admission under 1 year.	Beriberi cases.		Bottles of tikitiki extract distributed.
			Per cent.	
1923	3,735	1,127	30.17	9,960
1924	5,097	837	16.22	12,198
1925	5,644	434	7.68	12,153
1926	5,634	124	2.20	13,553
1927	6,501	165	2.54	15,932
1928	7,003	132	1.88	17,055
1929	6,787	121	1.78	17,149
1930	7,245	173	2.39	13,174
Total	47,646	3,113	6.53	111,174

Dr. T. Elicaño, in his letter of transmittal, remarks of this table: "The number of admissions in the puericulture centers (in the city) increases yearly, while the beriberi cases decrease notably and are *proportional* to some extent to the number of bottles of *tikitiki extract distributed;* the same technical personnel continued in charge of those puericulture centers, so that the factor of appreciation from the point of view of diagnosis is eliminated practically."

The private medical practitioners in the city when questioned about the frequency of infantile beriberi, entirely agree that this old scourge is becoming rarer every day.

RÉSUMÉ

Briefly summarized, we find that after twenty-seven years, beginning from the memorable conference of October, 1904, by the late and eminent Manuel Guerrero, nineteen years after the glorious publication in 1912 of its specific remedy by Chamberlain and Vedder, this implacable and wanton enemy of breast-fed infants is now wane-ward bound. As a result of these two admirable events we will notice that while in 1906 our infant-mortality rate for the City of Manila was 476.17, to-day (year 1930) it is only 160.24. This diminution is due mainly to the reduction in the mortality from infantile beriberi, which, without the least shadow of doubt, has been successfully fought by tikitiki.

Such scientific success, within such a relatively short period, is seldom registered in the annals of medicine, a conquest beneficial both to the Philippines and to the scientific world because of its fundamental bearing on the problem of the treatment and control of functional, reversible changes of cardiac failure.

ETIOLOGY: CONSTELLATION OF CAUSES

LORD MOYNIHAN'S SENTENCE

In considering the causation of infantile beriberi, we must bear in mind that Lord Moynihan(24) aptly said, "Events in medicine are rarely dependent upon the solitary cause, and Medicine is perhaps distinguished from all other sciences, not only by the number and interaction of possible causes, but by the remoteness, apparent irrelevancy or obscurity of causes whether immediate or proximate." Infantile beriberi is a disease in which exists a veritable constellation of causes, each and every one of which has its own relative value. These diverse factors in the production of infantile beriberi are the following:

SEASON AND CLIMATIC CONDITION

Humidity, rainfall, temperature, and atmospheric pressure, undoubtedly exert some influence. As may be seen in our monthly tabulation, beriberi comes under observation oftener during the rainy than the dry season, and although it occurs throughout the year, it begins to increase in August, reaches its maximum in December, and gradually declines until July. In Japan the greater number of infantile beriberi cases is observed from May to October, more particularly in July and August. Ohta(25) claims that there is no uniformity in the yearly incidence and mortality. In some years cases and deaths from beriberi are more than in others.

REGIONAL DISTRIBUTION

I have the impression that in the Philippines the regions that are heavily punished by beriberi at the present time are the urban communities, which are densely inhabited and where living conditions are in marked contrast with those of the rural districts. In my short survey in the Bicol provinces in 1913 and occasional investigations in Tayabas and Nueva Ecija Provinces, I felt that many cases recognized as beriberi are not genuine beriberi. A more careful and conscientious study of this subject is imperative, in as much as observers in other countries where beriberi is endemic, notably R. McCarrison,(26) have pointed out that even in countries where milled rice is the staple food, it is only in certain localities that beriberi is met with. Furthermore, people living in nonendemic regions seem to acquire a potentiality which predisposes them to beriberi when they are transferred to endemic places, a potentiality which they carry with them on returning to nonendemic areas.

RACE

Infantile beriberi is never observed among Caucasians and is seldom observed among the white half-breeds; this has no explanation except the difference in the diet and the mode of living.

AGE

The effects of food deficiency are variable according to the age of the subject. Scurvy, for example, is observed during ages of 6 to 18 months; rickets between 3 months and 2 years. In infantile beriberi the younger the child the more frequent and the more severe the disease is.

As can be seen from the figures in the accompanying table, the most dangerous period belongs to the age group of 1 to 3 months

(30 to 120 days), comprising about 53.69 per cent of the cases. Following closely is that from 3 to 6 months; then from 6 months to under 1 year; 1 week to 1 month and, lastly, from 0 to 1 week. Fifty per cent of Professor Ohta's four hundred thirty cases belong to the age of from 2 to 3 months.(18) Guerrero and Quintos said, "Beriberi is a disease which only affects infants who do not reach the first year of life. The greater number corresponds to the age between one and three months." Of the different clinical types we have observed, that of the cardiac and aphonic forms occur generally before the fourth month, while the pseudomeningitic is more frequently met with after that age.

Congenital beriberi or the one occurring during the first week of life is exceptionally rare. It occurred only four times in our series of five hundred fourteen cases. Ohta saw it but once out of four hundred thirty cases and remarked: "In infants less than one month old, diagnosis is extraordinarily difficult, inasmuch as the symptoms are not quite distinct, and I was able to precise my diagnosis of beriberi but once and that was in an infant nine days old."

SEX

Guerrero and Quintos believe that there is some predilection for males, but according to my tabulation of five hundred fourteen cases, both sexes are affected in about the same proportion. The Japanese authors agree with Ohta that the proportion for females and males is 1: 1.6 to 1.9, or the frequency in males is almost double.

SOCIAL AND ECONOMIC CONDITIONS

Infantile beriberi is strikingly a disease of poverty, occurring very exceptionally among the rich and middle classes, so that physicians practicing among them may deny its existence. Ohta also believes that it is more prevalent among those belonging to the "lower strata of society."

Economic condition in itself is not certainly the cause of the disease, but it is the indulgence in a faulty unbalanced diet in the great majority of cases. Beriberic mothers belong to those people whose "food habits" are controlled by custom and prejudice. This faulty feeding leads to some deviation of the body fluids, milk included, from the normal constitution. The nursing mothers of the "lower strata of society" generally indulge

in a monotonous diet, which consists mostly of dried fish and an excessive amount of rice but is very poor in vegetables. According to McCarrison(26) this kind of diet has at least five faults; namely, poverty in protein, excess of starch, deficiency of certain minerals (calcium, sodium, and chlorine), and deficiency in vitamins A and B.

CONSTITUTION, "STATUS PASTOSUS" MOURIQUAND AND BERHEIM

Internal and hereditary factors are very important in the production of infantile beriberi, in consonance with the modern but fruitful constitutional doctrine which faded before the etiological promise of bacteriology with its exclusive external causes. In fact, formerly we ruled out the diagnosis of beriberi in those infants whose constitutions do not exhibit the seemingly trivial "plump" appearance recently termed by Mouriquand and Berheim(27) "status pastosus," which is equivalent to "lymphatism" or to "branchimorphic, megalosplanchnic" of Pende or Czerny's "exudative diathesis." Status pastosus is described as, "a particular state of nutrition with anemia, hyperhydration, linked frequently with spasmophilia and in some cases with rickets, a soil particularly favorable to sudden unexpected death," as it happens in cardiac beriberi. "Megalosplanchnic" is also defined as "characterized by the relative preponderance of the vegetative system in relation to the development of the system of the life of relation."

The great authority on adult beriberi, Scheube,(3) believed that 87 per cent of cases of beriberi occur in robust individuals, and in my observation infantile beriberi occurs in no less percentage in infants of "plump" appearance, and overfed rather than underfed. I generally hold that the mere presence of "hypotrophic" condition should put us on guard for further examination and revision of any diagnosis of infantile beriberi in them.

ASSOCIATED DISEASES

Shimazono,(28) in discussing the etiology of adult beriberi, pointed out that certain infectious diseases, such as influenza, typhoid, and tuberculosis, and certain chronic conditions, as anæmia, diabetes, and nephritis, are commonly associated with beriberi. In infants we have not observed any particular relationship between beriberi and any other disease, except bronchitis and bronchopneumonia which we found to have been, in some cases, in association with beriberi. Hirota found that sixteen of his early thirty cases were associated with bronchitis, intes-

tinal catarrh, scabies, bronchopneumonia, or eczema. Quintos and Guerrero, in their monograph, classified infantile beriberi into pure and mixed forms, the latter being associated with gastroenteritis, bronchitis, or convulsions.

BREAST FEEDING

All medical observers unanimously recognize the fact that breast feeding is the condition "sine qua non" (Guerrero and Quintos) for the production of infantile beriberi, and in my practice I do not remember having encountered a single case of infantile beriberi in an infant that was never breast fed by the mother.

It is true that in medical literature we read from time to time reports on cases of infantile beriberi in bottle-fed babies. Chapman(29) reported eight such cases in 1927. Ohta(25) claims to have seen sixteen among his four hundred thirty cases, and in the last three years we have gathered four cases of infantile beriberi in infants, who at the time of admission were not nursed by the mother's breasts. It should be emphasized here that the occurrence of these rather exceptional cases cannot, and should not, be construed as derogatory to what we have stated above, that breast-feeding is the condition "sine qua non;" because, in penetrating deeply into the feeding history of all these cases, we shall always be able to point out that these infants were nursed by their mothers, some time after birth and before the manifestations of beriberi in them. The history records of our four cases clearly demonstrate this striking fact:

Case 1. Infant, 6 months old, artificially fed at the time of admission for four months, but breast fed for the first two months.

Case 2. Infant, 9 months old, artificially fed for the last seven months, but breast fed for the first two months.

Case 3. Infant, 1 year old, artificially fed for almost a year, but received mother's milk during the first week of life.

Case 4. Infant, 8 months old, mixed-feeding.

Guerrero and Quintos, in discussing the kind of feeding, unconditionally upheld that, "Only a cursory and insufficient investigation or erroneous attitude on the part of the physicians may induce them to believe in the existence of infantile beriberi in artificially-fed infants." In support of this dogmatic assertion they presented the three following observations which are translated here in detail:

In the month of January of this year (1910), one of us (Quintos) was called to see a five-month old child, at Lara street; and he was found to have all the symptoms of hyperacute beriberi. The mother was asked of

its feeding, and he heard with surprise that the little sick one was bottle-fed. It was hard to believe this, because it was in opposition to his daily experiences; but inasmuch as the mother swore that the food of the child consisted solely of condensed milk and nothing else, there was nothing to do but believe it, recording it in his memorandum as the first case of beriberi acquired not through maternal feeding. This child died. A few days later, this same physician went to visit a child in the contiguous house, who was nursed by the mother and attacked also by beriberi. Upon hearing this diagnosis, the mother exclaimed, "Therefore the sickness of my child is the same as the one that killed the child of my neighbor!" "How do you know it, madam?" asked Dr. Quintos. "Why not, since I gave my breast to that child two times when one night it was left to my care?" At last was found the cause of that beriberi, which otherwise would have been an argument against that which up to the present time has been traditionally observed, that infantile beriberi is encountered only among breast fed infants.

The second case was observed by M. S. Guerrero. To a female twenty-six-day-old child, an acute attack of "taon" came on October 3, 1908, preceded for about nineteen days by incoercible vomitings, restlessness, taquipnea, aliguria, etc. Guerrero was then called to see her, and to withdraw her from her mother's breast, she was inscribed in "Gota de Leche" for artificial feeding. With this, the symptoms improved, and the child seemed to be in full convalescence, when one night Guerrero was again urgently called, because the little girl was again under an attack. The return of the malady greatly astounded him. He asked the mother whether, following the advice given her, she abstained giving the breast; and she assured him that she had, and that since the child was enrolled in "La Gota" the infant did not receive any other food except cow's milk. Reminded, however, of the custom of our mothers to sleep by the side of their children, he asked her some more questions, and the woman confessed that on several occasions, when she happened to wake up at night, she found her child peacefully sucking her breasts. We came to find out again the cause of an attack of beriberi in an artificially fed child.

There can exist, therefore, no doubt as to this etiological factor. And if we are still required to give more proof, we can relate another case which has the value of a laboratory experience.

The wife of the janitor in one of the banks in this capital acquired beriberi during her pregnancy, and gave birth to twins, a boy and a girl. To the boy she gave condensed milk, and to the girl her breasts. Fifty-two days after birth, or, on July 8th, 1907, the girl suffered from a hyperacute form of "taon" and died. The boy, on the other hand, fed artificially, developed perfectly, without having had any symptoms of beriberi.

PECULIARITIES OF THE CAUSAL RELATIONSHIP BETWEEN MOTHER'S MILK AND INFANTILE BERIBERI

In analyzing the causal relationship between infantile beriberi and mother's milk three puzzling peculiarities should be noted.

1. That the severity of the disease in infants is not directly proportional to the severity of beriberi in the mother. Most of the fatal cases of infantile beriberi come from mothers with

the rudimentary form of the disease and vice versa. There are cases of severe maternal beriberi without affecting the offspring.

2. Notwithstanding the absence of either objective or subjective symptoms of beriberi in the mother, beriberi is observed in infants in a great number of cases. I agree with Ohta's estimate that about 25 per cent of the cases are of this type. In my own judgment, this phenomenon of "symptomless" beriberi in the mothers has no other explanation than what Charles Nicolle and Charles Lebailly(30) call "infection inapparent," as applied to the apparently symptomless phase of some infectious diseases, which can be detected with improved technic, and which occurs naturally and plays an important part in the spread and prolongation of an epidemic. Likewise, these mothers are true beriberi subjects, in which the beriberi is in the "inapparent phase."

More recently, Mouriquand(31) calls attention to what he terms "inapparent distrophies" (les distrophias inapparentes) or "symptomless distrophies." He said that in experimental scurvy there exists a trophic coefficient peculiar to each individual animal, which may produce either a manifest (with symptoms) condition of deficiency (carence) or a symptomless state of predeficiency (pre-carence) ; and the latter can be detected by means of new and improved technic.

The existence of many of such cases of "inapparent" beriberi in mothers (without objective or subjective symptoms) is supported by daily observations here and abroad. I have seen mothers in whom the symptoms of beriberi began to be manifest some time after their children had died of infantile beriberi. Hirota, of Tokyo, in his second communication, mentioned three cases in which the manifestations of beriberi in the mother were retarded fourteen, twenty-nine, and thirty-two days, respectively, after its appearance in the infant. What is at fault, I believe, is the lack of a minutely conducted examination, or the lack of improved methods and technic to detect the symptoms. Guerrero and Quintos, in this connection, emphatically said, "And in reality, if we will not lose sight of many of these cases, surely we will witness the development of the disease whose manifestations were *latent on the day of the examination.*"

3. That the production of beriberi is independent of the duration of breast-feeding from beriberic mothers. We have seen and treated cases of infantile beriberi in which the history of breast-feeding was of comparatively short duration. One of

our four bottle-fed cases previously mentioned, gave a history of having been breast-fed for only one week, and the cases mentioned above by Guerrero and Quintos were breast-fed for very short periods.

EXPERIMENTAL BERIBERI

Andrews(19) performed an experiment, trying to reproduce beriberi by feeding seven young puppies, 2 to 14 days old, with milk of beriberic mothers for a period of one month, in order to determine that beriberic milk is probably deleterious by reason of what it lacks rather than because of any harmful constituent. Andrews summarized the results of the experiment as follows:

> All of these puppies showed incoördination and weakness of the extremities, particularly of the hind legs. In all slight degeneration of the peripheral nerves by the Marchi method was demonstrated. All showed œdema and anaemia of the subcutaneous tissues. These findings agree entirely with those of the infants dying of beriberi. However, only one of the puppies showed the dilatation and hypertrophy of the right heart which I have regarded as a constant finding in infantile beriberi. In my opinion these experiments furnish, therefore, additional evidence that the condition described as infantile beriberi is due simply and solely to the ingestion of the mother's milk.

This experimental beriberi indicates that beriberi in infants differs in many respects from animal beriberi, and the clinical observations confirm this distinction, in as much as we never observed incoördination and weakness of the extremities, and that the heart, in infants, is particularly the organ severely affected.

DEFICIENCY DOCTRINE

In order to explain the action of the milk of beriberic mothers in the causation of beriberi, it was believed, since Hirota's time, that infantile beriberi was due to an intoxication, but this theory gradually weakened because of the failure to demonstrate the presence of such a mysterious toxin and, finally, it was completely abandoned, with the discovery of the extract of tikitiki, its specific remedy with which infantile beriberi is rapidly cured without resorting to weaning. We feel that it is unnecessary to discuss the infectious theory due to *B. mycoides* and *mesentericus* of Jose E. Montes,(32) which he claimed to have obtained from the liver, bone marrow, and pleural fluid of beriberi patients and with which he produced the disease in animals by inoculation of these organisms, for the simple reason that such microörganisms were never demonstrated to be present in human milk, nor have confirmatory findings been made by other investigators.

Furthermore, the whole clinical process and treatment of infantile beriberi do not present any evidence that it is of an infectious origin.

Based upon experimental medicine and clinical observation, we believe that infantile beriberi is a true deficiency disease, in the sense that beriberi milk lacks vitamin B, a "hormone food" or "functional food," which is indispensable to the preservation of a proper "internal medium" and normal physicochemical metabolism.

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ILLUSTRATION

TEXT FIG. 1. Infant-mortality and infant-beriberi rates per 1000 births (transients included) in the City of Manila by years. 319